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THE RAND/TAC INFORMATION AND ANALYSIS SYSTEM: VOLUME II— THE ANALYSIS PROGRAMS AND PROCEDURES

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PREFACE

The RAND/TAC information and analysis system provides for the collection, processing and analysis of operations, maintenance and supply data, using an IBM 1401 computer to assist in data purification and in the management and evaluation of aircraft operations and support at base level. The system is unique in that the data collected are identified with the specific sortie (and in some instances to the specific leg within the sortie). This allows the user to perform many kinds of analyses not ordinarily possible, relating mission use to reliability, manpower and spares usage.

The system grew out of a number of special field tests (e.g., Rapid Roger, Skoshi Tiger, Tack Down) exploring the feasibility of using a small business computer to assist with materiel and operations problems at base level. In the tests prior to Combat Dragon, it was necessary to "create" the maintenance analysts through an extensive educational process. Combat Dragon was unique in that Air Force personnel carried out the entire project from data collection through final writeup with no assistance from RAND, other than the initial training in the use of the system.

It is now possible to organize the loose collection of notes, procedures and programs into a formal system description. Accordingly, this RAND effort comprises four Memorandums containing essentially the package of materials used in training the Combat Dragon team. The information is organized as follows: Volume I (RM-5666-PR) is for data collectors and editors responsible for providing the data bank to be used in subsequent analyses; Volumes II (RM-5667-PR) and III (RM-5668-PR) are for analysts (especially people who will be doing maintenance analysis) to familiarize them with the available programs and analysis products, and to encourage them to ask questions and explore the data in an imaginative way; and Volume IV (RM-5669-PR) is for the "data services branch" of the evaluation or analysis team, to identify procedures and to impart an understanding of what the analyst is attempting to do.

Surprisingly, even though the system is entirely computerized, readers need not have a knowledge of computer hardware and software to follow the text. A knowledge of the details of aircraft weapon systems would be useful, for although we describe such operations, the descriptions are somewhat cursory. In particular, a familiarity with aircraft maintenance procedures would be useful.

The concepts, techniques and programs of the RAND/TAC information and analysis system should be adaptable to future Air Force base-level management information systems, whether manual or highly mechanized. Provided that the appropriate computer is available, the RAND/TAC system can easily be introduced at a base and used without modification for field tests or other purposes. Recent changes in a number of standard Air Force forms and in data linkages, however, may make them preferable to the RAND/TAC forms for a particular base exercise.

With modest changes to current Air Force data collection procedures and reprogramming of the analysis packages, the system would provide a valuable supplement to current base analysis reports--a supplement more attuned to questions that are and should be asked by base maintenance management. The system will also provide a detailed guide and check list for the design-development of new base-level information systems and should provide direct input to analysis portions thereof.

SUMMARY

The RAND/TAC information and analysis system provides for the collection, processing and analysis of operations, maintenance and supply data, using a small business computer to assist in data purification and in the management and evaluation of aircraft operations and support at base level. It is unique in that operational and logistics variables are interrelated through several features of the data and analysis systems to permit identification of operational events connected with a particular sortie and relate these to explicit maintenance or supply actions preceding or following the sortie, management actions, and key environmental conditions.

The system consists of a series of forms for collecting operational data, maintenance actions, maintenance manpower availability, aerospace ground equipment utilization, supply demand, cannibalization and issue data, a series of computer programs and manual procedures for editing, reformatting and processing to provide basic displays, and other programs to provide basic analysis packages. The system is designed to minimize duplicative recording of data elements, and has flexible computer programs to permit a wide variety of analyses.

The four volumes constituting this effort present a complete system description, together with instructions on how to perform analyses using the system programs. Volume I (RM-5666-PR) contains the description of and procedures for collecting and editing the data--the forms, procedures and program operating instructions. Volumes II (RM-5667-PR) and III (RM-5668-PR) are concerned with the analysis programs and procedures, and with analysis design and methods. The first emphasizes how the programs work, the second how questions can be answered. In a sense both volumes are written for a career that currently does not exist in the Air Force: the maintenance analog of the operations analyst. A person interested in this field should be versed not only in maintenance but also in data processing, computers, statistical methods and experimental design.

Each time RAND participated in a special field test, such as Combat Dragon, Skoshi Tiger, and Tack Down, it was necessary to "create" the maintenance analysts by an extensive educational process. Volume

II attempts to encapsulate the first part of that educational process. It introduces the prospective analysts to the data bank, the programs and the procedures needed to process the operations, maintenance and supply analysis data.

Volume III is based on the second stage of the learning process. It assumes that the user has now mastered the elements of the program and can focus his attention on answering questions. Thus it addresses analysis fundamentals: dependent and independent variables, data fields, sorting, data selecting and tagging. Then it discusses a variety of areas of interest to maintenance management and shows how each can be explored with the system. Finally, some of the background and philosophy of experimental design is discussed.

Volume IV (RM-5669-PR) describes the computer programs used with the system. To encourage a rapprochement between the analysts and the programmers, we have attempted to include sufficient information for the programmer to understand the general outlines of what the analyst is attempting, as reflected by the functions of the computer programs.

ACKNOWLEDGMENTS

It is impossible to credit all those who made contributions to the system. Hall Logan (TAC-OA) and Sergeants James Fisher and Melvin Ericson (TAC) provided most of the maintenance procedures. Calvin Gogerty (RAND) designed the entire supply inclusions. Chauncey Bell (RAND) designed the "off-equipment" bench repair procedures. Sergeant Jack Marshall and Technical Sergeant Elias Martinez contributed to the 1401 programming, as did Mrs. Colleen Dodd of RAND. Major John Munkvic is chiefly responsible for the operations aspects. A special thanks is due Miss Doris Dong of RAND who did the art work.

CONTENTS

GLOSSARY

Abort rate	The rate of aborted sorties made by a unit in a given period. The most frequently used equation is the following: abort rate = sorties aborted/sorties attempted.
Action taken	The type of maintenance performed: repaired, removed and replaced, calibrated, etc.
AGE	Aerospace ground equipment.
AGE utilization	A display showing both active and standing flight-line utilization of AGE.
Aircraft display	Also called flight-line display and flight-line queue sort. Shows pictorially the maintenance and status history of each aircraft for a 24-hour period.
Base-line	Such data are counts of the times an event was attempted, e.g., sorties flown in a certain category.
Break-rates	Along with write-ups, break-rates are the major independent variables in determining aircraft recovery and turnaround, and are therefore the major determiners of sortie generation capability. Break-rates are determined for both aircraft and aircraft systems. The equation is as follows: break-rate = system fix count/sorties flown.
Chi-: are	An analysis program that makes statistical comparisons of frequency counts to determine whether nonrandom behavior exists.
Code 799	No defect discovered.
Code 800	Removed or replaced to facilitate maintenance.
Code T	Removed for cannibalization.
Code U	Replaced after cannibalization.
Combat Dragon	An exercise with A-37A aircraft in Vietnam.
Cost-effectiveness	An exercise with F-4C aircraft at MacDill Air Force Base.
Daily package	Processing of operations, maintenance, supply and scheduling data by means of edit, error listing, and aircraft and work center displays.
Delay time	The accumulation of work interruptions on each system and each work center, by aircraft.
Demand rates	Most frequently, supply demand rates. Most frequently, demand rate = demand (request)/ sorties flown

Deviation-Degradation (DEVDEG) program	A computer program. Lists and counts missions' deviation-degradation data from the 308 forms.
Dichotomous data	Data that has only two categories: for example, yes-no, 0-1, hit-miss, aborted-nonaborted, malfunctioned-nonmalfunctioned.
Easy data	Data collected by one person at a single collection point, as opposed to tough data.
Edit mask card	Locates the decimal phase that is edited into the data field just before printing.
Edit program	Searches for and identifies errors, reformats data, relieves data recorder of all possible unnecessary burden.
Eight/two pocket	Card drop pocket on the 1401.
Eighty-eighty (80-80) listing	Records are printed as they exist on the card (or tape) without separation of the fields.
Error listing	An image of each card containing a computer-detected error plus a description and location of each error.
ETIC	Estimated time to in-commission status.
ETR delay code	Equipment temporarily removed.
Field location card	Locates low- and high-order positions of the fields on the record.
Flight-line display	See aircraft display.
Frequency Counter (FREQ) program	Searches any field of unknown and unsorted data, builds a table, and counts the frequency of entries in the field.
Gang punch	To punch identical or constant information into all of a file of cards.
Gross fix time	Period from touchdown to end of maintenance. Includes unscheduled maintenance only.
Gross turnaround	Period from touchdown to end of maintenance, includes both scheduled and unscheduled maintenance.
Hard data	Keypunched data, as opposed to soft data.
Harmonic mean	The method of computing helps minimize the effect of unequal sample size by using the reciprocal of n.
Hourly Frequency Accumulate	A program that computes the frequency counts for resource utilization for each of the 24 hours during the day.
How malfunction code (how mal)	Describes the nature of the malfunction: burned, distorted, cracked, overheated, etc.

Independent variables	May affect system behavior, as opposed to dependent variables, which are the things being affected.
KBA	Killed by air.
K-97 report	Deck of maintenance data forwarded to the Logistics Command.
Lag time	Period from touchdown until maintenance begins.
Man-hours	Hours of direct labor.
Manpower Utilization Sequence	Relates personnel utilization (direct on-equipment labor) to sorites flown. Manpower utilization — Searches each minute of the hour to find the number of men working each hour. Manpower available — Produces a summary card showing the number of men available for each hour of each work center day. Touchdown counts — Produces a card for each day showing the number of touchdowns for each hour of that day.
Mission essential items	Essential items for accomplishing the objective of the sortie.
MDC	Maintenance data collection portion of AFM 66-1.
MND	Maintenance nondeliveries.
Net fix time	Active fix time when work is being accomplished. Lags and delays are not included, refers only to unscheduled maintenance.
Net turnaround	Same as net fix time except it includes the scheduled maintenance as well.
NORM	Not operationally ready, maintenance.
NORS	Not operationally ready, supply.
NORS-G	Not operationally ready for supply, grounded.
N/P pocket	Card drop pocket on 1401.
NRTS	Not reparable this station.
Observed frequency	Count of successes, failures, aborts, etc.
Off-equipment file	MDC records of bench repair actions.
On-equipment bench repair	Repair done without item going through conventional materiel control channels.

OR rate	Operationally ready rate: OR rate = hours ready/hours possessed.
Oxnard format	The output format of the Edit program always includes clock hours. Oxnard refers to the project for which the format was designed.
Oxnard project	An exercise with F-101 aircraft at Oxnard Air Force Base.
Pearson product moment correlations	Statistical measure showing the amount of relationship between two measures.
PS code	Primary-secondary code. A column (in record format Ms) for use as a squadron (or other) designator.
Quantitative data	Manhours, elapsed time. Contrasts with frequency count data.
Rapid Roger	An exercise with F-4C aircraft in Thailand.
Recombine program	A special purpose program used in the Recovery Sequence. Eliminates duplications, adds a dummy sortie card to the end of each tail number subset and merges the sortie deck output by Single, First and Last with the nonsortie data output by Compute Elapsed Time.
Recovery Sequence	Preprocessed edit output data. This involves computing elapsed times, converting to Julian Calendar, and coding the sortie data for first, last and single sorties of the day. Requires Col. 80=0, =2, =3 records. Involves four programs: Compute Elapsed Time: Single, First, and Last; Recombine; and Clint.
Recovery Summary (RECSUM) program	An analysis program. Provides a complete, readily comprehensible summary of aircraft recovery and turnaround in a one-page general summary with back-up pages containing detail.
SAC Full Force	An exercise with B-52, B-47, KC-135 and KC-97 aircraft.
Sequential Frequency Distribution	Summarizes and displays events across 24-hour period.
7-cards	Produced by Clint program. Aircraft recovery records that include only the unscheduled maintenance action and the postflights. Aircraft turnaround records that include both scheduled and unscheduled maintenance data.
8-cards	Produced by Clint program. System records that include both scheduled and unscheduled maintenance actions.

9-cards	Produced by Clint program. Work center records that include the scheduled and unscheduled maintenance actions of all work centers.
Sick bird analysis	Determines whether individual tail numbers show atypical write-up rates based on the sorties flown, by obtaining the sortie and write-up counts for each aircraft card, using Chi-square testing for nonhomogeniety.
Single, First and Last (S/F/L) program	A special program used only in the Recovery Sequence. Makes a single sortie card from the pairs of sortie cards resulting when a flight crosses midnight. The program also determines and tags by tail number the sequence of sorties flown each day.
Skoshi Tiger	An exercise with F-4C, F-5A, and F-100 aircraft in Southeast Asia.
Soft data	Data not keypunched, as opposed to hard data. Generally verbal information.
Sortie length	Measured from takeoff to chock time (engine shut-down).
Sparrowhawk	An exercise with F-4C, F-5A, and A-4 aircraft at Eglin Air Force Base.
Splattergrams	Displays write-ups, sortie-by-sortie, to give a snapshot history of each aircraft. Program computes write-up rates for each aircraft and prints them at the end of each tail number.
Spread-field list	Provides a listing with each field isolated from the adjacent one by blanks. Much easier to read than an 80-80 listing.
Support general codes	Scheduled maintenance codes.
Supply 1050 system	The 1050 is the standard supply computer.
System repeat write-up analysis	A repeat write-up is identical to the write-up on the previous sortie.
Tack Down	An exercise with C-130 aircraft at Pope Air Force Base.
Throughput time	Time it takes to get a job out of the computer, measured from request to delivery.
Tough data	Data collected by many persons at many points, tough to get.
TMS	Type, model and series of aircraft.

Turnaround data	Output that includes all maintenance actions.
Units produced	A count of maintenance actions. Each job is assigned one unit of work.
Vector	A record that describes the status of a system at a given time.
When discovered code	Code showing when the malfunction is discovered: before flight, during flight, during inspection, etc.
Work Center Display	Also called work center queue sort. Shows 24-hour pictorial history of work center.
Work unit codes analysis	Summarizes on one page all the meaningful information on form 300 records for each work unit code.
Write-ups	A malfunction is "written-up," i.e., described. Along with break-rates, write-ups are the major independent variables in determining aircraft recovery and turnaround.
Z-score	Score expressed in sigma units.
ZI	Zone of Interior (USA)
Zone punch	11-punch (-) or 12-punch (+) on card used when punching Alpha or special characters.

I. INTRODUCTION

The philosophy behind the design of the analysis programs described in this Memorandum involves two closely related maxims that we follow, as far as possible:

1. Avoid special purpose programs that can process only a single data type and produce only a specific product. Instead, emphasize general purpose programs; these are format free and can be applied to a variety of problems.
2. Use a modular construction. This implies the ability to tie together several general purpose programs with a series of instructions to the computer operator who can then obtain a desired output.

The most common sequence in our analyses consists of four operations (modules): select, tag, sort, process.

1. Select a subset of the data (e.g., 2-digit system recovery data for January and February).
2. Tag the data (e.g., separate the pre-modification from the post-modification records, and identify "tag" both groups).
3. Sort (e.g., majoring on 2-digit syste code and minoring on tagged codes).
4. Process (e.g., compute an analysis of variance for each system to determine the impact of the modification on recovery time).

These four general purpose modules are preferable to one special program. Although a general purpose program could be written, since it is easy to visualize a program using the four modules as subroutines, we feel it is easier and often quicker to use the computer operator as the "master program." This attitude about modular design is adopted principally because the development of new modules expands the capacity for analysis, whereas the development of a master control program only adds a degree of elegance to the existing capacity.

The philosophy is not without cost. It puts a much greater demand on the user who must

a. know what is in the data;

b. know what the programs can do with the data;

c. be able to visualize the compatible combination of a and b that will yield the information he desires;

d. be able to provide the machine operator with the procedures necessary to link the program modules together to achieve meaningful output.

Because much analysis is a kind of creative exploration, it is desirable that the analyst, the programmer, and the machine operator work together much more closely than is traditional. Often the procedures are developed by mutual discussion; hence, comptroller personnel play an active role in obtaining the end products. The most responsive system, of course, is one where the analyst functions as his own programmer and machine operator. Such a system is practically obtained only by synergic behavior.

It is to the creative user that we direct our Memorandum. At best, since most of his creative ability will come only with experience, we hope to assist him through the first trials. To help develop the facility sketched above (particularly item c), we have included several possible uses for each general purpose program. To follow the subsequent exposition the user will not need to know programming, but he will require some data processing vocabulary--field, record, file, alpha, alpha-numeric, gang-punching, and sorting by majors and minors--as indicated in the example of a data file shown in Fig. 1.

SEX	GRADE	WEIGHT	
BOY	7TH	120	8
BOY	7TH	123	8
BOY	8TH	127	8
BOY	8TH	121	8
BOY	8TH	129	8
GRL	7TH	110	8
GRL	7TH	111	8
GRL	8TH	114	8
GRL	8TH	117	8

Fig. 1--A 9-record data file

A data file consisting of nine records is shown. Each record (a punched card in this instance) contains four fields: the sex, grade, and weight of each individual, plus a gang-punched "8". The records are sorted first by grade, putting the 7's in front of the 8's. Then they are sorted by sex (i.e., major on sex and minor on grades also expressed, sorted by grade within sex). The entries in the sex field are alpha; grade, alpha-numeric; weight, numeric.

II. THE ANALYSIS PACKAGE

The analysis package has two major divisions: the recovery sequence that summarizes data by sortie, and the analysis programs that process the data from the recovery sequence and the editing sequence.

RECOVERY SEQUENCE

Before processing with the Clint program, which summarizes data by sortie, the recovery sequence must preprocess the edit output data (see Vol. I). This involves computing the elapsed times, converting to Julian Calendar, and coding the sortie data for first, last, and single sorties of the day. The recovery sequence uses the edit output tape of tail-number display data sorted by time within tail-number sequence.

Major	Col.	79	AN	PS code
	Cols.	35-38	N	tail number
	Cols.	11-12	N	month
	Cols.	9-10	N	day
	Cols.	13-16	N	hour-minute
	Col.	80	AN	card code
Minor	Cols.	73-78	AN	report number

Because the recovery sequence requires only the Col. 80=0, =2 and =3 records (the maintenance, sortie and status records), the input can be restricted to reduce the processing time. The special CET output tape T1 is used for this purpose. The sequence involves four programs used in the following order:

1. Compute Elapsed Time (CET) adds the elapsed time and Julian day to each record, and splits the data into two groups--the sortie records and all other data.
2. Single, First, and Last (S/F/L) combines the two records that result from sorties flown across midnight, and makes the first, last, and single sorties of the day determinations for each aircraft.
3. Recombine merges the sortie data output from step 2 with the non-sortie data output from step 1. Recombine also eliminates duplicate records and adds a dummy sortie record (that the Clint program may require) at the end of each tail-number subset.

4. Clint summarizes the data by sortie.

These four programs are described in detail below.

Compute Elapsed Time (CET)

The Compute Elapsed Time program is a general purpose program that computes the elapsed times of edited data (Oxnard formats described in Volume I), and converts the Gregorian start time to the Julian dates that Clint requires. Some formats, like the comments and sortie deviations, for example, do not include stop times; when the computer senses such cards, it omits the elapsed time computations. CET can also be used as a general purpose record selector. It may be used to select and punch all the data of a given card type by punching the desired card code from Col. 80 of the data record into Col. 3 of the program control card (format C13). If tape input is used, punch the tape count in Cols. 1-2. See Fig. 2 for the CET program setup. Recovery sequence processing requires sorting in the flightline display sequence.

For general processing control, switch action is as follows:

Switches I/O and A are always "on".

Switch B--"on" for card input.
"off" for no tape output.

Switch C--"on" for tape output (on unit 2).
"off" for no tape output.

Switch D--"on" to punch only the card format selected by the input control card.
"off" to punch all cards

Switch F--"on" to eliminate sortie cards from output. This special setting is used for the recovery sequence; the sortie cards are punched, processed, and recombined with the data. This setting provides a sortie free file to combine with the processed sortie cards.
"off", all output is written on the output tape.

Switches G and E--Not used.

When CET is used as a part of the recovery sequence, the following procedures are used.

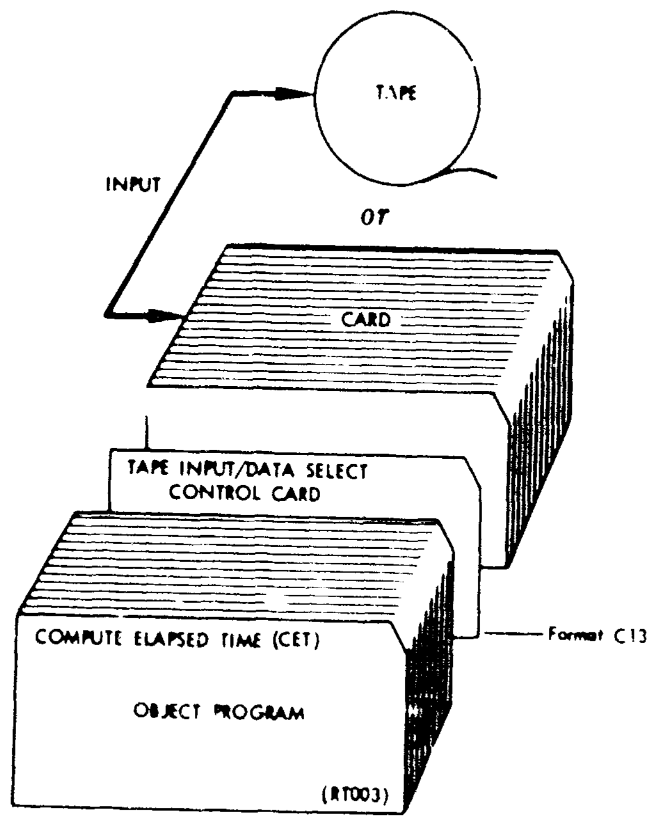

Fig. 2 -- Compute elapsed time program setup

Punch a numeric "2" in Col. 3 of the control card (format C13) to obtai sortie card punch-out.

Switch B--"on" for card input.
"off" for tape input (tail number display tape).
The input tape must be mounted on unit 1.

Switch C--"on" to write output on unit 2, and Switch F "on" to eliminate the sortie cards from the output on unit 2.

Switch D--"on" to indicate that only selected cards (i.e., numeric "2" in Col. 80) are being punched.

The tape on unit 2, tape T1, is saved for processing with Recombine, and the deck of sortie cards is processed by Single, First and Last.

Single, First and Last (S/F/L)

S/F/L i a special purpose program used only in the recovery sequence. It makes a single sortie card from the pairs of sortie cards resulting when a flight crosses midnight. Takeoff time is taken from the first card of the pair, the touchdown from the second, and the elapsed time is recomputed. The program also determines and tags by tail number the sequence of sorties flown each day. Single sorties are tagged "S", the last sorties of the day are tagged "L". All others are tagged "F" for first. Sortie data must be sorted in the tail number display sequence. Figure 3 shows the S/F/L program setup.

Switches I/O and A are set "on". No other switches are used.

Recombine

Recombine is a special purpose program used only in the recovery sequence. It eliminates duplications, adds a dummy sortie card to the end of each tail-number subset (the Clint program may need this), and merges the sortie deck output by S/F/L with the non-sortie data output by CET. Recombine has two inputs--the sortie data processed by S/F/L and the sortie-free data output by CET, i.e. tape T1. Figure 4 shows the Recombine program setup.

Switches I/O and A are set "on".

Switches B through F--not used.

Switch G--"off" prints duplicate records eliminated from file. "on" eliminates printing.

CET's output tape, tape T1, is mounted on unit 1, and a scratch tape is mounted on unit 2. The object program is followed by a control card (format C9) containing the number of input tapes. The output tape from Recombine, called the T2 tape, is used as input to the Clint program.

Clint*

Except where necessary, the following discussion addresses Clint as a single program, although it was necessary to split the original

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*The program is named for Clint Smith who uses it extensively in SAMSON, a maintenance-operations model. See T. C. Smith, G. D. Brown, P. A. Mason, R. Moulenbelt, and H. J. Shukiar, A User's Manual for SAMSOM II: The Support Availability Multi-System Operations Model, The RAND Corporation, RM-4923-PR, November 1967; and G. D. Brown, R. Moulenbelt, and H. J. Shukiar, A Programmer's Guide to SAMSOM II, The RAND Corporation, RM-5235-PR, November 1967.

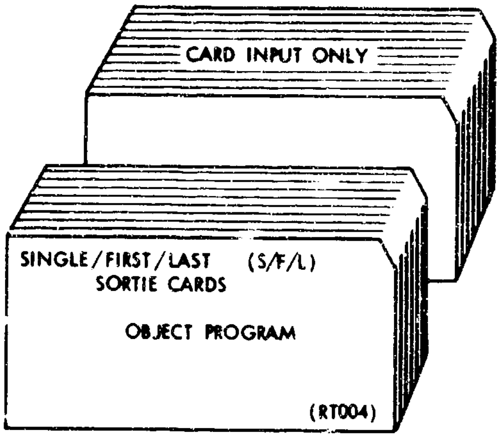

Fig. 3 -- S/F/L sortie cards program setup

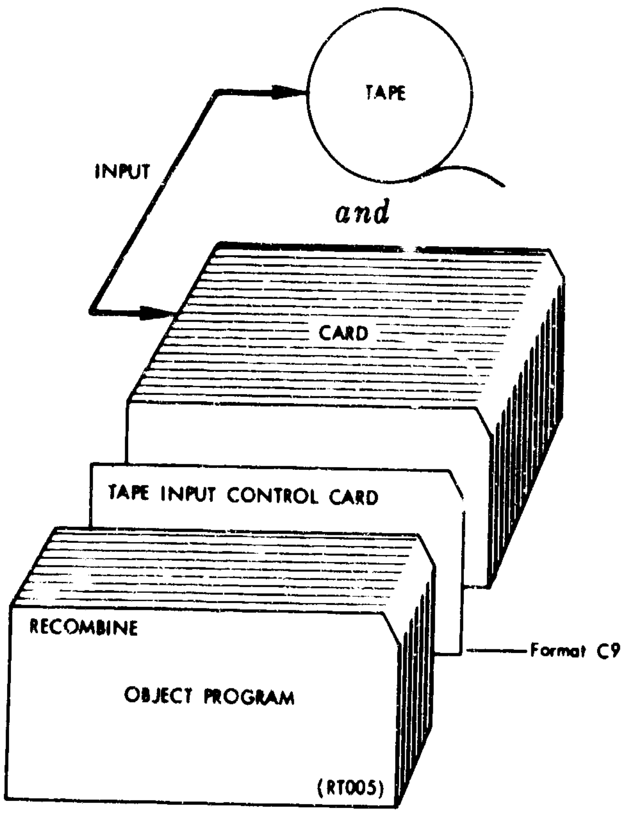

Fig. 4 -- Recombine program setup

7044 package into two separate programs for the 1401. One program computes the aircraft and system summaries, the other computes the work-center summaries. Clint summarizes data by sortie, and provides inputs for most of the analyses. For this reason, it is the most important program in the analytical package. Accordingly, it is described in much greater detail than the others.

Early in our efforts to develop computerized methods for analyzing maintenance data, it became evident that we could make more meaningful analyses by relating all information to the specific sortie. The greatest advantage of gathering data by sortie is that it provides two measures: the means (aborts, recovery times, break-rates, write-up rates, etc.) and the variances (the distributions of the scores around the means). Only by having both is it possible to make definite statements such as "write-up rates have significantly increased this month."* The variance data enable us to test various write-up rates and determine whether a true difference exists among them.

Data that can be gathered by the sortie fall into four major categories:

1. Operational data. Who flew where on what kind of mission with what kind of success?
2. Sortie (debrief) data. What tail number flew or aborted at what time and what equipment malfunctions occurred?
3. Maintenance data. What resources were required (and for how long) to recover the aircraft from the effects of the sortie? Status, off-equipment and cannibalization data are also included.
4. Supply data. What parts were provided or backordered to make the recovery?

Currently, Clint only combines item 2 and the on-equipment portions of item 3. This combination provides most of the data necessary to determine the day-by-day functioning of the flight-line. (Volume III describes the technique for combining all four data elements.)

The sortie summary of the aircraft is computed by dividing the aircraft into a number of individual black boxes whose repair is

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*A. Sweetland, Some Statistical Methods for Maintenance Analysis, The RAND Corporation, RM-4443-PR, April 1966.

ordered in time. This is seen in the simplified display of Fig. 5. The program sweeps through the data (ordered by time within tail number sequence) as illustrated. As the program encounters each new sortie record, it outputs the summarized data of the previous sortie, and begins summarizing the data of the next sortie.

The computer keeps three kinds of records.

1. The aircraft record. This includes the lag until work first starts, the length of the work, and the length of any work interruptions (delays). Records are kept of a considerable amount of associated information: Man-hours, units, sortie length, sortie type, etc. These are defined below.
2. The systems record. A similar accounting is kept for each of the aircraft's major systems. Since it is desirable to vary this list of systems from time to time, control is provided through the use of system tables (format M3). The computer processes only data identified in the tables. For example, the user may not be interested in maintenance done under support general system codes, so he eliminates the codes from the tables.
3. The work center record. This keeps a record of each work center's actions, and is identical to the system record. Similarly, it is controlled by reading in a table of work centers (format M1).

The aircraft record is always produced even if no action occurs. To minimize data volume, however, the system and work center records are output only when a maintenance action occurs. Had the data of Fig. 5 been processed, the result would have been one aircraft record summarizing the complete recovery, one system record for the flight-control system, and two work center records, one for the hydraulic shop and one for the electrical shop.

Clint output (formats R1, R2 and R3) contains two types of data--quantitative (e.g., man-hours) and categorical (e.g., sortie types). The quantitative elements are described first. All times are given in hours and tenths of hours.

1. Lag time (Cols. 28-32). This is measured from touchdown. For the aircraft record, lag time ends when maintenance begins. System and work center lags end when work begins on each specific system or by each specific work center. In Fig. 5, lag time for the hydraulic shop begins at 1200 and ends at 1500 when that shop first begins work. Lag for the electrical shop ends at 1300, as do the lags for the aircraft and the flight-control system.

```
      12  13  14  15  16  17  SORTIE SYSTEM SHOP
   FFFF                    FCF
           2222                         FLTCTL ELECT
                    2222                FLTCTL HYDRL
                          FFF FCF
```

Fig. 5 -- Functional check flight of an aircraft

(A functional check flight (FCF) touches down at 1200 hours. After a lag lasting until 1300 hours, a two-man team from the electrical shop works for an hour on the flight-control system. This is followed by a delay until 1500. The hydraulic shop then works for an hour on the same system. The aircraft then repeats the check flight.)

2. Delay time (Cols. 33-37). These are accumulations of work interruptions on each system and on each work center. Recording is kept by aircraft (no work on any system is being accomplished).
3. Net fix time (Cols. 38-42). This is the active fix time when a maintenance data collection (MDC) record indicates work is being accomplished.
4. Gross fix time (Cols. 43-47). For the aircraft record, this is the time measured from touchdown to the end of maintenance. By definition, gross fix time for the aircraft record is the sum of lags, delays and net fix times. For system and work center records, however, gross fix time excludes lags.
5. Units produced (Cols. 58-60). These are defined by AFM 66-1. The measure is essentially a count of maintenance actions. Each job having a definite beginning and end (e.g., each repair job, each TOC, each bench check) is assigned 1 unit of work.
6. Man-hours (Cols. 61-65). This accumulates man-hours consumed in direct labor.
7. Sortie length, also referred to as flying hours (Cols. 66-68). This is measured from takeoff to chock-time (engine shut-off) whenever possible, rather than from takeoff to touchdown. Life begins at chock-time in the world of maintenance.

The following categorical items always appear on the records. When used as major or minors (i.e., independent variables), they allow the user to compare information thus far discovered to effect aircraft recovery and turnaround.

1. PS code (Col. 1). Primary-secondary code. Most frequently this is used to separate data by aircraft type or squadron, but it has also been used to separate flights. This entry is controlled by the tail-number table used in the edit program and is a local option.
2. Card code (Col. 2). The aircraft (sortie) record is coded 7; the system 8; and the work center 9. These records are referred to as the 7-, 8-, and 9-cards.
3. Tail-number (Cols. 03-06).
4. Date (Cols. 7-15). Year, month, day, hour and minute. Note that the field defined by Cols. 1-15 is in the most frequently used sorting sequence.
5. Take-off time conversion code (Col. 16). Depending on the time constants in the program, take-off time may be recoded as "A", "B", or "C" work shift--morning, afternoon or night, etc. We are currently using "D" for day (0530-1730 hours) and "N" for night.
6. Sortie configuration, also called sortie type, contains the type of sortie flown (Cols. 17-19). Combat and firing range codes generally describe the type, numbers, and locations of ordnance carried.
7. P and H code (Col. 20). The program senses the MDC data for the type of maintenance. If the code indicates that a periodic, phased, or hourly inspection has taken place, a "P" or "H" is shown. Because these inspections may take several days, it is often desirable to exclude them for analyses concerned with immediate turnaround capability.
8. SFL code (Col. 21). This code indicates whether the sortie was the single, first, or last sortie of the day for the tail number appearing in Cols. 3-6. This code, particularly when combined with the take-off time code, allows the user to determine how scheduling affects recovery and turnaround. Since scheduling affects recovery and turnaround more than any other variable, the reader is encouraged to explore this effect. See RECSUM section for suggestions.
9. NORS-G code (Col. 22). If a NORS-G (Not Operationally Ready for Supply, Grounded) status card is sensed, the data are tagged with a "G". It is often desirable to exclude these data when computing turnaround capability.

10. ASW code (Cols. 23-27). Entries here differ by card type. The aircraft record (Col. 2=7) is blank in this field and can be used for special identification. The system records (Col. 2=8) contain the 2-digit work unit code (Cols. 23-24 only); the work center records (Col. 2=9) contain the work center in Cols. 23-27.
11. Identification (Cols. 69-80). Twelve characters are provided for run identification. It is particularly desirable to use this when several different kinds of runs are made from the same data.

The coding that appears in Cols. 17-19 (load configuration) is not a fixed requirement. Any desired identification may be used, depending on local needs: special exercises, flight crews, call signs, unique missions, mission success-failure, released-nonreleased-impounded aircraft, combat damage, and so on. These can all be made part of the permanent record by minor changes in local coding requirements. Although 3 characters seem like a limited number, using 24 alpha and 10 numeric provides for 40,000 combinations (3^{34} power).

Several special features of Clint are described below. Maintenance preceding the first sortie and following the last sortie that each aircraft flies is excluded from the summaries; it is generally not known whether these represent complete sets of data. Most peacetime flying schedules, however, are completed before the end of the month, and the aircraft are recovered immediately. The data for this last recovery can be retrieved by using the dummy sortie records that Recombine provides. Switch action on Clint controls the use of the dummy sortie records.

Occasionally, the user wishes to omit data containing atypically long recovery times. For example, an aircraft may stand in NORS-G for several days before recovery can be completed. Such atypical data can be eliminated by using the lag and delay constants entered on the control card (format C1). Lag and delay times are compared with these constants; when the constants are exceeded, the record is not produced. The reader is urged to try using the constants of 999.9 hours (circa 6 weeks), select the long gross recoveries, and consult the flight-line displays to see what is happening. We discourage using small constants until the analyst is familiar with maintenance practices.

When Clint is output on tape, the aircraft record (Col. 2-7) also gives a complete recap of system break-rates. Beginning in Col. 94 of the tape record, the program builds a table corresponding to the table of system codes used; for instance, Col. 94=system 11, 95=system 12, etc. If the system requires maintenance, a numeric "1" is entered; if not, the column is left blank. The count of the "1's" (called total write-ups) is recorded in Cols. 131-132. The aircraft break code is in Col. 130, so that if any system requires maintenance, record "1", otherwise "Blank".

The concepts of write-ups and break-rates are only meaningful when applied to unscheduled maintenance.* Our procedure has been to include system codes 11-97 plus the postflight (system 03200) to obtain a complete recovery picture. Then, when computing break-rates and write-up rates, the postflight actions are deleted by the switch settings provided by both RECSUM and the Analysis of Variance programs described below. Control of write-up computation is also provided by the input table construction, as described below.

When aircraft status records are included, the program will summarize the NORM (not operationally ready, maintenance) and NORS-G entries. These data are useful when exploring the problem of inflated gross fix times, but we discourage their use unless the information is needed by sortie, which is rarely the case. Provision is made to get a complete status analysis, as described in the section on Analysis of Variance.

The following suggestions and comments are intended to help the user during the frustrating time when he is making his first learning runs.

The most important thing to remember is that processing and output are controlled by the tables of work centers (format M1) and work-unit codes (format M3). Data that do not match both tables are not processed, see below. Hence, when the tables do not include all the work centers and work-unit codes contained in the input data, the 7-, 8-, and 9-card man-hour and unit summaries will not agree unless

*Unscheduled maintenance is also referred to as recovery time, get well time and time to OR. Output that includes all maintenance actions (systems 01-97) is called turnaround data.

identical tables are used. During exploratory phases we suggest using the Frequency Count program (described later) to get these tables. Later, since this produces an awesome number of records, the reader will wish to become more discriminating. To do this, he will need to know the following program sequencing.

The program first senses for a legal work center code; that is, the work center on the record exists in the work center tables. Having found a legal code, the computer next tests for a legal system code. Then it does the necessary calculations and bookkeeping for both the work center and system codes, and updates the summary for the aircraft record. Note that only when a legal work center and system code is found, will there be an updating of the aircraft record. This sequence can be used to limit output by excluding the unwanted work center or system from the tables.

The table of 2-digit system codes also controls the break-rate and write-up records appearing in Cols. 94-132 of the aircraft records. Only systems punched "1" in Col. 3 of the system tables are included in the output. By convention, this is unscheduled maintenance (system codes 11000-97000, plus postflight actions, system code 03200). This output can be generated by switch action control.

Occasionally, it is necessary to explore the support general codes beyond the 2-digit level. This is accomplished by recoding the data. Assume one wishes to explore the uploading sequence. The various system codes on the input records can be recoded: UM for upload, munitions; UT for upload tanks, pylons; UI for upload inspections and checks; and so on. These recoded data are combined with the sortie records and processed by Clint. The system tables must also include the special codes. When this information is processed, it generates a summary of the uploading sequence.

The MDC, sortie, and status data that Clint uses must have been processed in the recovery sequence described using programs, CET, S/F/L and Recombine. Data must be sorted by time within tail-number sequence.

A control card (format C1) containing the lag and delay constants and run identification is required. We suggest punching 9's in Cols.

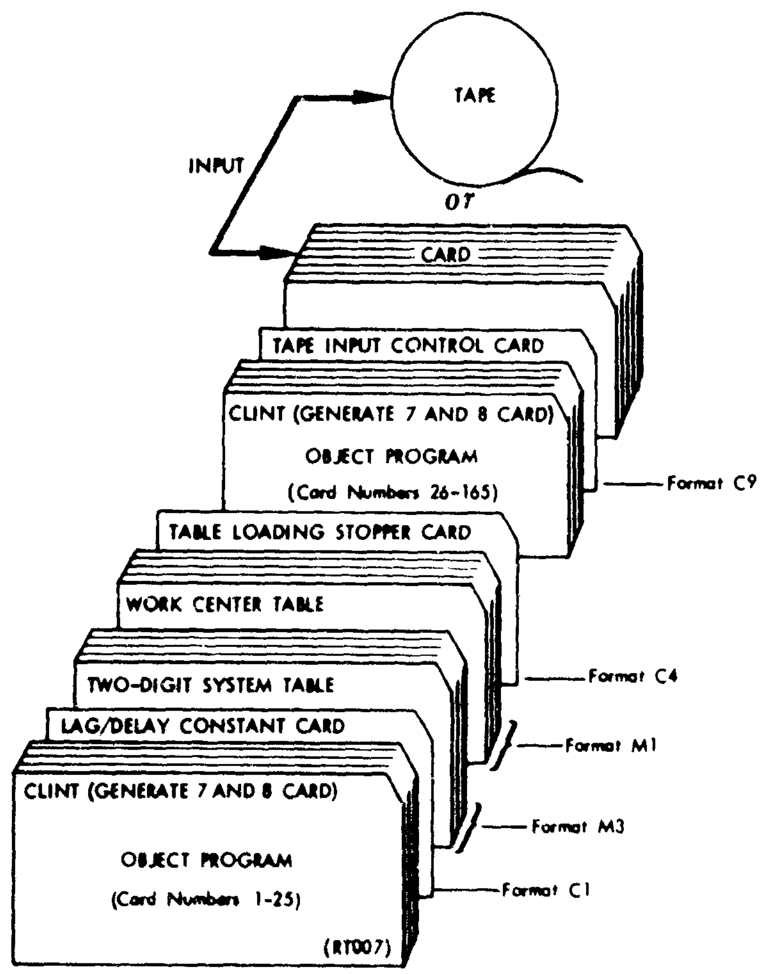


Fig. 6 -- Clint (generate 7 and 8 card) program setup

1-8 of this card as a standard procedure. The tables of systems (format M3) and work centers (format M1) must be inserted between cards 17 and 18 of the Clint object deck since a program overlay is necessary. Columns 72-75 of the object deck identify card series. The tables must be sorted in ascending sequence by system or work center, and must contain no duplicate records. The tables are followed by a table loader stopper card (format C4) containing an 11-4-8 punch in Col. 80. A control card (format C9) containing the count of the number of input tapes is placed behind the object deck. See Figs. 6 and 7.

Clint requires the following switch actions:

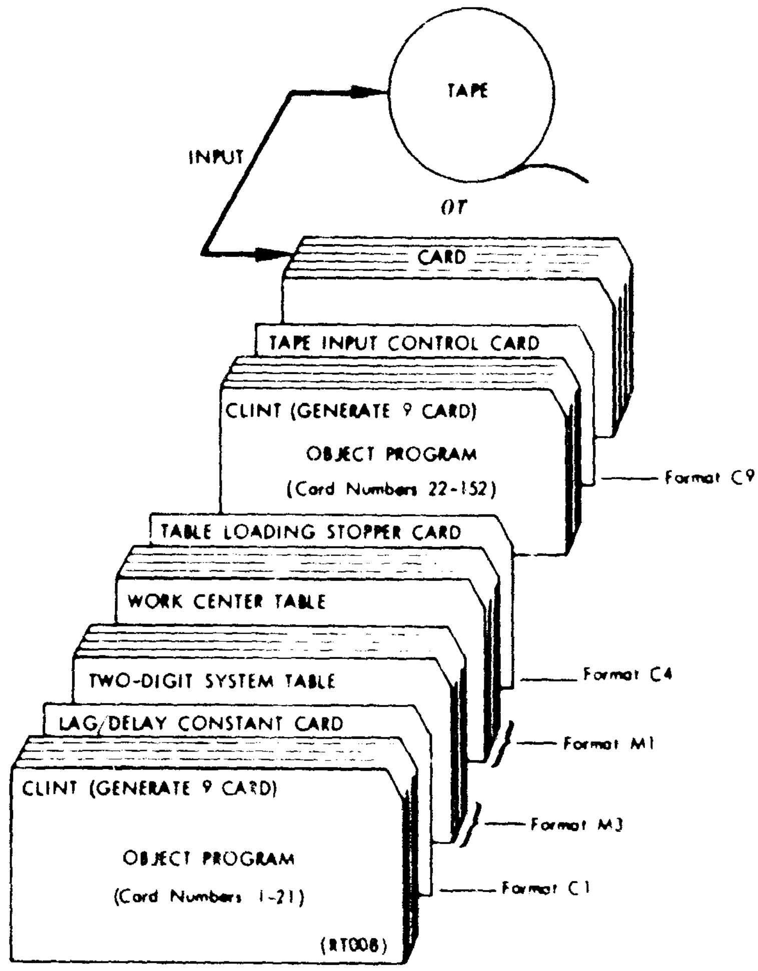


Fig. 7 -- Clint (generate 9 card) program setup

Switches I/O and A are always "on".

Switch B--"on" card input.
"off" tape input (tape T2 on unit 1).

Switch C--"on" to include all systems in the input table when computing the various data elements.
"off", the support general codes are tested and only 03200 is used in the computations. That is, switch C "off" produces the recovery data.

Switch D--"on" for card output.
"off" for tape output (tape on units 2 and 3).

Switch E--"on" to use the dummy sortie record produced by Recombine.
"off", the dummy sortie record is skipped, thus eliminating maintenance following the last sortie.

The input tape is mounted on unit 1. Tape units 2 and 3 are used to write output. The sortie records appear on tape unit 3 (format R1); the system record or work center records (formats R2 or R3), depending on which program is used, appear on tape unit 2.

THE ANALYSIS PROGRAMS

Recovery Summary (RECSUM)

Most of our program development efforts have dealt with special exercises. A major concern has been how to determine what happened as quickly as possible: an exercise is, literally, an exercise with unknowns. The Recovery Summary program (RECSUM) attempts to deal with this problem by providing a complete, readily comprehensible summary of aircraft recovery and turnaround in a one-page general summary with back-up pages containing detail, as illustrated in Figs. 8 and 9.

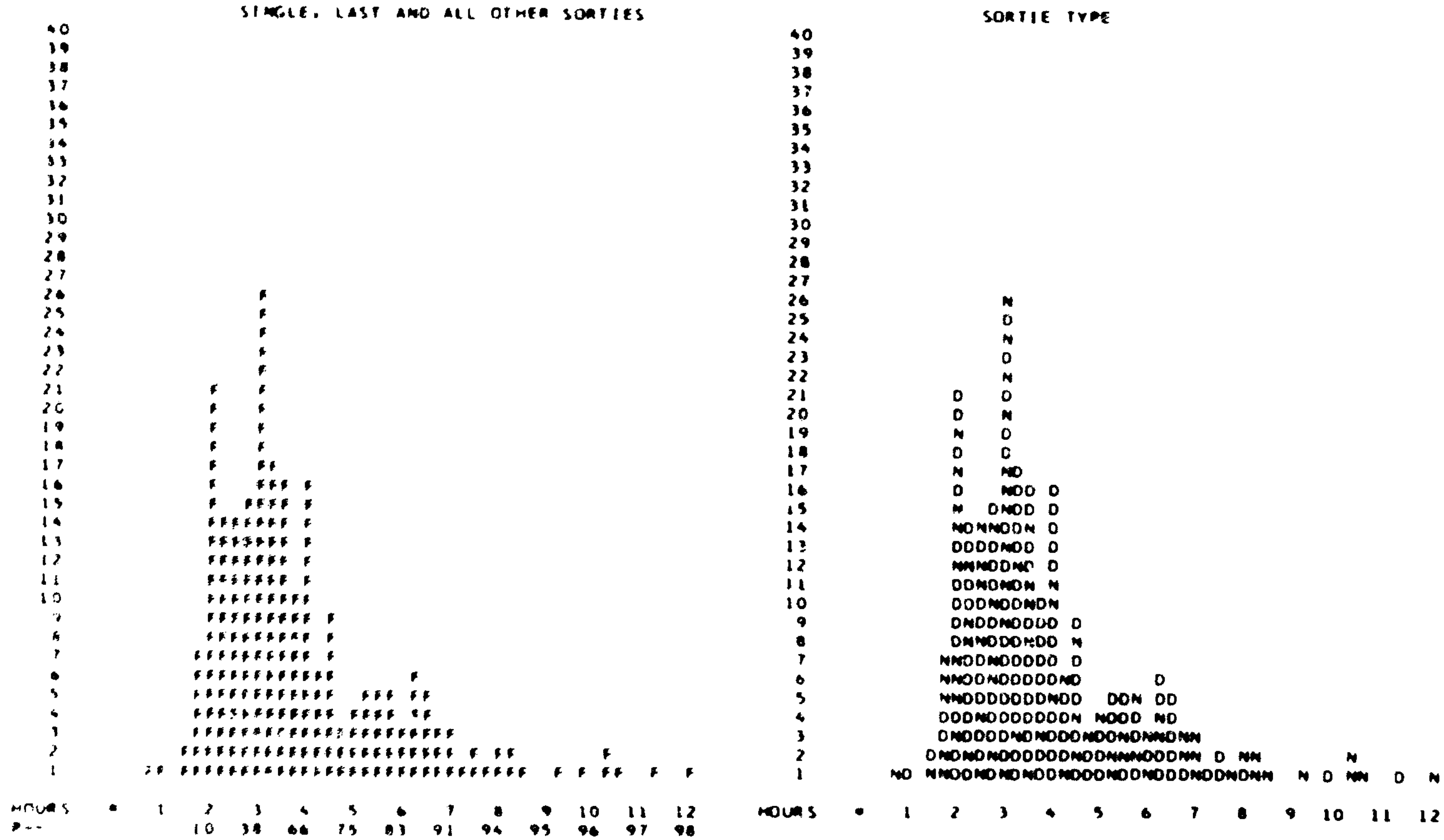
RECSUM is a special purpose program in that it accepts only Clint output. The program first produces a one-page pictorial and numerical summary for each selected minor, followed by a one-page total data summary for the major. The majors and minors are the analyst's option. For example, he can obtain a summary of the 7-card recovery data for each tail number plus a summary for the entire squadron by minoring on the tail number (Cols. 3-6) and majoring on the PS code (Col. 1). Using the 8 cards, the analyst can obtain a summary for each system by minoring on Cols. 23-24 (system code) and majoring on the card code. He can also select the data field he is most interested in--net or gross recovery. The computer then gives him a detailed pictorial and numerical summary of this field, plus a gross summary of all other data fields.

The details of the RECSUM output (see Fig. 9) are the following:

1. Major and minor fields. These entries are the locations of the record as indicated in the control card (format C3) and show the low- and high-order positions of the fields.

2. Titles. The analyst selects these. In general, the title (format C10) should define the major and the data sample. The two subtitle cards (format C11) should describe the mnemonic codes appearing in the matrix.

MAJOR-- 7 COLS 2- 2 SAMPLE AIRCRAFT TURNAROUND TIME DISTRIBUTION - S/F/L
MINOR-- F COLS 21-21



AVG-- 4.08 SIGMA-- 2.31 N-- 237 STDERR-- .15 VARIANCE 5.32 TOTAL-- 967.2
TOTAL SORTIES 243 6 SORTIES REQUIRED NO FIX TIME BREAK-RATE-- 98/100--- .975
TOTAL MANHOURS-- 3214.7 SATURATION INDEX-- 3.3 AVG T/A ALL SORTIES--- 3.98

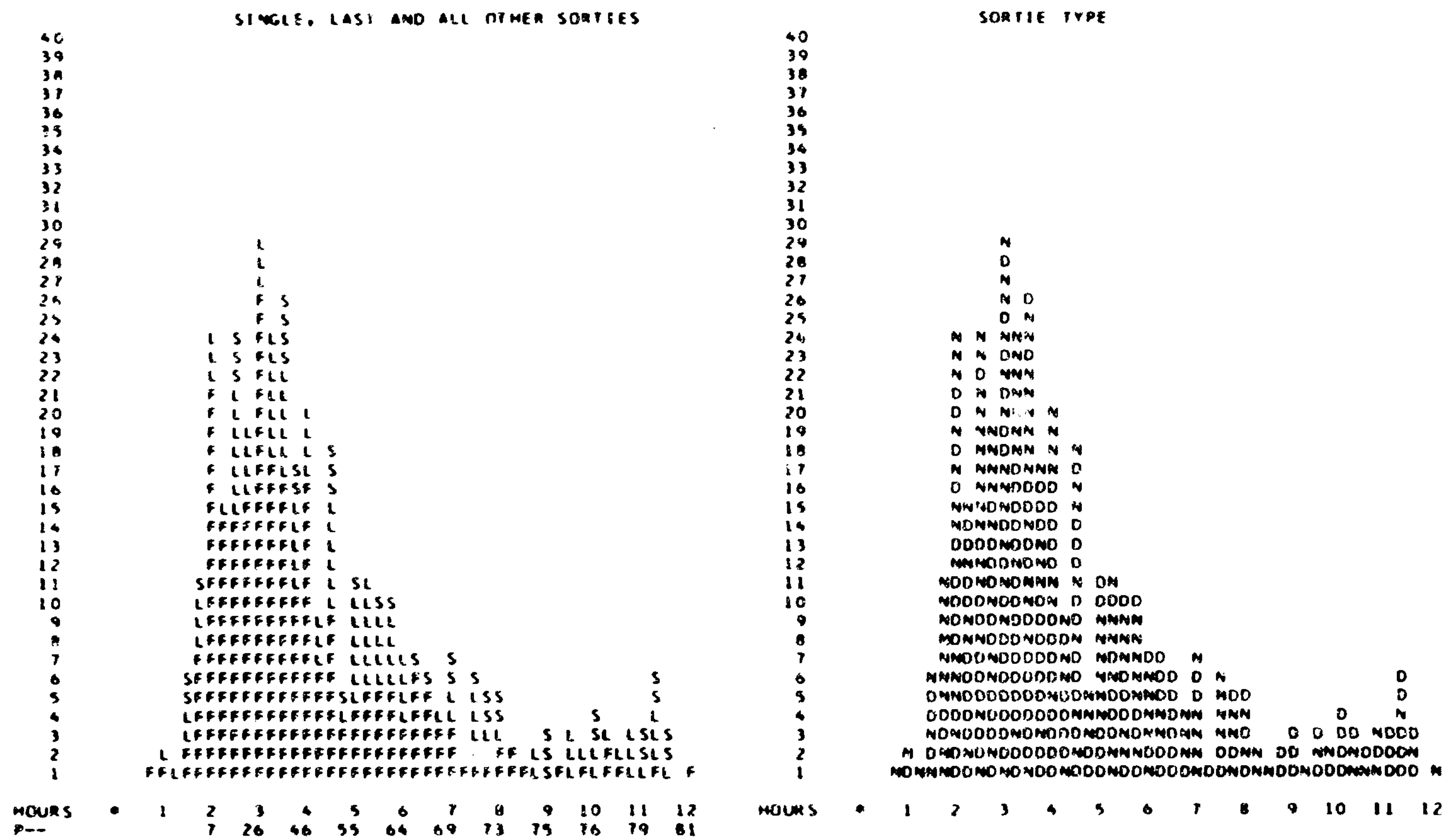
* ITEMS GREATER THAN 12 HOURS
OUT OF BOUNDS DATA ARE COMPUTED BUT NOT PLOTTED

FILE TOTALS

	LAG	DELAY	NET	GROSS	UNITS	MANHOURS	FLY-HRS	WRITE-UPS	BREAKS	NORS	NORM
TOTALS--	7.4	452.1	967.2 ****	1456.7	3028	3214.7	316.5	329	142	47.3	441.9
AVG--	.16	1.91	4.08	6.15	12.78	13.56	1.30	1.39	.60	.20	1.86

Fig. 8 -- Aircraft turn round time distribution

MAJOR-- 7 COLS 2- 2 SAMPLE AIRCRAFT TURNAROUND TIME DISTRIBUTION - S/F/L



AVG-- 8.01 SIGMA-- 10.62 N-- 464 STDERR-- .49 VARIANCE 112.88 TOTAL-- 3716.8
TOTAL SORTIES 480 16 SORTIES REQUIRED NO FIX TIME BREAK-RATE-- 97/100--- .967
TOTAL MANHOURS-- 11508.6 SATURATION INDEX-- 3.1 AVG T/A ALL SORTIES--- 7.74

84 ITEMS GREATER THAN 12 HOURS
OUT OF BOUNDS DATA ARE COMPUTED BUT NOT PLOTTED

FILE TOTALS

	LAG	DELAY	NET	GROSS	UNITS	MANHOURS	FLY-HRS	WRITE-UPS	BREAKS	NORS	NORM
TOTALS--	159.2	2193.6	3716.8 ****	6069.4	8879	11508.6	661.0	1126	334	6247.3	2519.5
AVG--	.34	4.73	8.01	13.08	19.14	24.80	1.38	2.43	.72	13.46	5.43

Fig. 9 -- Aircraft turnaround time distribution

3. Ordinates. These are column counters.
4. Hours and P. This shows the percentage of the sample terminating by a certain hour; for example, 7 percent of the jobs or recoveries are completed by one hour, 35 percent by two hours, and so on. These percentages do not include the zero duration data.
5. Average, sigma, N and other conventional statistical computations. This line includes only the nonzero data.
6. Total sorties. A better term would be total records in the sample. This entry includes the zero-duration data, followed by the number of zero-duration records. Break-rate is calculated by dividing the nonzero records by the total record count.
7. Saturation index. This should be viewed with caution when sample size is less than thirty. It is computed by dividing the total man-hours by the total net fix time to yield the average team size when active maintenance is being accomplished.
8. Average turnaround for all sorties. This computation includes the zero-duration records. It is obtained by dividing "Total" (shown on the right) by the record count.
9. Lags, delays and similar terms. These are defined in the discussion of Clint.

This program has frequently been used to explore the effects of daily flying schedules on aircraft recovery. In this instance the minor is Col. 21 of the sortie cards that contain the S/F/L information. As a general statement the F sorties indicate average maintenance time when it is known the aircraft will fly again that day. Comparing F and L sorties gives a picture of how much deferred maintenance is taking place. The S sorties show the behavior when recovery is done without pressure. The major field is generally the PS code (Col. 1).

RECSUM also writes (on tape unit 2) a record of the summaries at each break in the minor (see format Y). This can be used to obtain summary data from all the 7-, 8-, and 9-cards by sorting on the appropriate entry. For example, a summary for each tail number within the squadron could be obtained by majoring on the squadron (Col. 1) and minoring on the tail number (Cols. 3-6). Similarly, a summary for each day could be obtained by minoring on the day (Cols. 10-11).

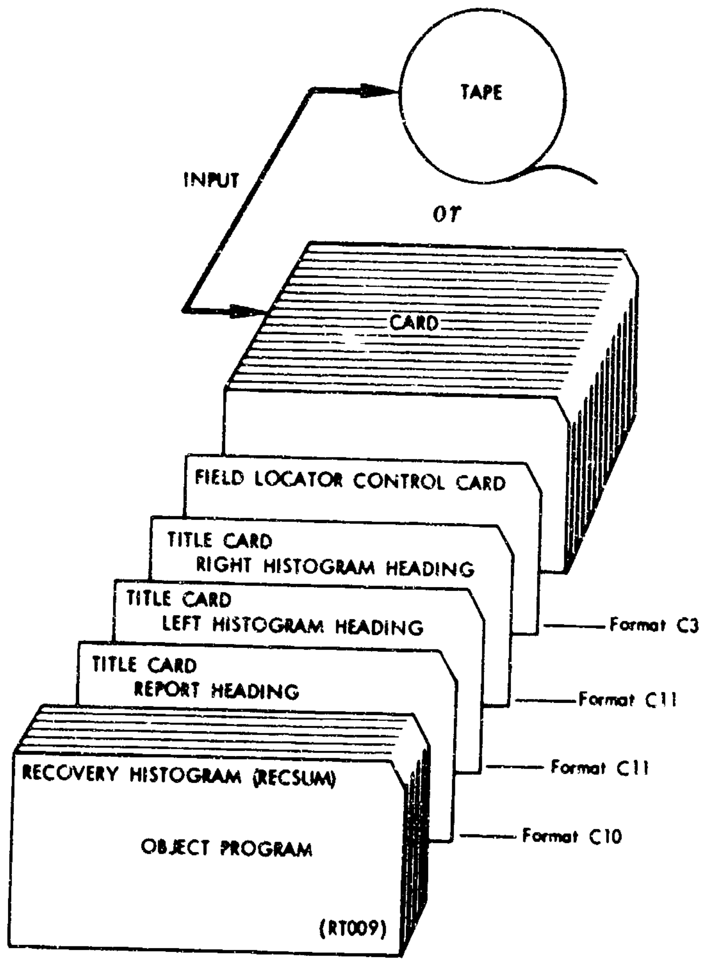


Fig. 10 -- Recovery histogram (RECSUM) program setup

When using RECSUM, data must be sorted by major and minor. Four control cards are required, as shown in Fig. 10.

1. A general title card (format C10).
2. A heading (title) for the left-hand histogram (format C11).
3. A heading for the right-hand histogram (format C11). Note that the histogram entries may be any of the single-digit codes appearing on the data cards: squadron, aircraft type, sortie types, load configuration, shift.
4. The field control card (format C3). Note that numeric "4" is always punched in Cols. 1, 4, 7, 10, 13, 16 and 19, and numeric "2" is always punched in Col. 22. Field 13-15 of the control card identifies the location of the character that will appear in the left-hand histogram (S/F/L). Field 16-18 identifies the location of the right-hand character (sortie type).

Field 19-21 defines the beginning of the data field on Clint output that the program is to treat in detail. Field 22-24 defines the location of the asterisks that tag the item being detailed. The relationship between these two fields is fixed and only the following pairs are legal.

Desired Item Detail	Cols. 19-21 are Punched	Cols. 22-24 must be Punched
Lag	432	215
Delay	437	225
Net recovery	442	235
Gross recovery	447	245
Units	460	255
Man-hours	465	265
Sortie length	468	275
Write-ups	532	285
Breaks	530	295
NORS	452	304
NORM	457	315

Col. 80 of the field control card must have an 11-3-8 punch. Either card or tape(s) input may be used.

Switches I/O and A are always set "on".

Switch B--"on" for card input.
"off" for tape input (tape on unit 1).

Switches C and D--not used.

Switches E, F and G--"on" eliminate, respectively, FCF data, hourly and periodic data, and postflight data (work unit code 03200).

Samples using the same title and control cards may be stacked.

When Clint is output on tape, and the Col. 2-7 is used for input to RECSUM, the aircraft write-up and break rate summary will appear on the output.

Because of the large amount of information provided and the many ways of sorting Clint output, it is impossible to make any complete description of what can be gained by using the RECSUM program. As an alternative, we suggest that the reader make three separate test runs. The first, described previously, should use the sortie data (Col. 2-7), majoring on the aircraft type and minoring on the S/F/L codes. The second should use the system cards (Col. 2-8), majoring on the squadron and minoring on the system codes (Cols. 23-24). The third should use the work center data (Col. 2-9), majoring on squadron and minoring on the work centers (Cols. 23-27). If the reader compares the results of these three runs, he will have a good idea of the kinds of recovery summaries available, plus an understanding of how to use the program. Further, if he processes the same data with the Analysis of Variance program (which only involves changing control cards, since sorting has been done), he will have made a big stride toward understanding the very complex problem of analyzing maintenance.

Analysis of Variance

This program computes a one-way analysis of variance.* Because it produces most of the parameters used to define quantitative data, it has become the most general purpose of the programs. Most frequently the program's input comes from Clint. Its next most common input comes from the CET program. Input may be either cards or tape, and samples may be stacked. Since most of the intermediate storage is on tape instead of core, there is virtually no limit to sample or subsample size. There is also no limit to the number of samples that may be stacked.

The program prints the subsample means, n, raw score totals, and variances, as well as a distribution of the subsamples (grouped in half-sigma units from the sample means). Subsample means are tagged with one, two, or three asterisks (0.05, 0.01, and 0.001 levels) in terms of "statistical distance" from the harmonic mean of the sample. See Fig. 11. In addition, the program provides a number of specialized processings controlled by switch action. Zero data may be excluded from the computations. A constant such as sorties flown may be read in for converting data counts to break-rates. Selected data may be punched out to be used as input to the Chi-square program.

The general usefulness of the Analysis of Variance program is greatly facilitated by the equivalent of a "variable read format"

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*See Sweetland, ibid., for a discussion of how Analysis of Variance can be used for analyzing maintenance data.

SAMPLE FREQUENCY DISTRIBUTION

EXERCISE - NET FIX TIME - UNSCHEDULED MAINTENANCE (INCLUD.S POSTFL) CODE-- 5

FREQUENCY COUNTS

																	MEANS	N	TOTALS	VARIANCE
Z--		2-	1-	0	1	2	3	4	5											
SIGMA		2.4- / 1.4-	.3- / .7	1.8 / 2.8	3.9 / 4.9	6.0 / 7.0	8.1 / 9.1	10.1 / 11.2	12.2 / 13.3											
SAMPLE 1--	F	14	509	184	29	19											1.26**	755	953.7	.48
SAMPLE 2--	L	5	177	224	53	14	18	7	1	5	1	6	1	1	1		2.19*	518	1133.6	4.79
SAMPLE 3--	S		19	9	7	6	4	1	3	1	2	1		2			4.66***	59	275.0	38.29
SAMPLE TOTALS		19	705	417	89	39	22	8	4	6	3	7	1	3	1		1.77	1332	2362.3	
CUMULATIVE PERCENT		1	54	86	92	95	97	98	98	98	98	99	99	99	99					

OUT OF BOUNDS DATA BELOW AND/OR 8 ABOVE NOT PLOTTED

ANALYSIS OF VARIANCE

	SUM SQUARE	DF	MEAN SQUARE	F
BETWEEN	777.7273	2	388.8636	102.1068
WITHIN	5061.3672	1329	3.8084	
TOTAL	5839.0945	1331	4.3870	

Fig. 11 -- Analysis of variance

(When using this program as a general purpose report generator, ignore the statistical computations, since emphasis is on the means, N's (record counts), and totals. The major sense is shown in the upper right following "Code--"; the minor sense is given along the left margin beside the sample numbers. Under "Frequency Counts" the distributions are grouped in half-sigma clusters as indicated by "Z--" showing the Z-scores and corresponding standard deviations, "Sigma". In addition to the conventional statistical computations (variances and F-test), the harmonic mean of the total sample is computed along with its standard error. Sample means lying outside the 5-, 1-, and 0.1-percent bounds are tagged with 1, 2, or 3 asterisks, respectively.)

SAMPLE FREQUENCY DISTRIBUTION

SAMPLE - WORK CENTER ANALYSIS - NET FIX
0480 02 07-07 23-27 38-42

CODE-- 9 SORTIES-- 480
SWITCHES A-9---------- ON

FREQUENCY COUNTS

Z-- SIGMA	2- 3.9-	1.2-	1- 1.4	4.1	C 6.8	9.4	1 12.1	14.8	2 17.5	20.1	3 22.9	25.5	4 28.1	30.8	5 33.5	36.1	MEANS	N	TOTALS	VARIANCE	BREAKS AVERAGE
SAMPLE 1-- 11110			5														.40**	5	2.0	.03	.00
SAMPLE 2-- 11120			21	2													.93*	23	21.5	.80	.04
SAMPLE 3-- 12035			11	5													1.59*	16	25.5	2.90	.05
SAMPLE 4-- 12041			53	57	9	6	3	1					1				4.26	131	557.5	21.65	1.16
SAMPLE 5-- 12042			19	34	10	3	2	1		1							4.65	70	325.5	11.62	.68
SAMPLE 6-- 12043			64	42	13	5		1									3.50	125	437.4	4.71	.91
SAMPLE 7-- 12044			51	27	3	3	1		1								3.20	86	275.2	5.82	.57
SAMPLE 8-- 12051			2	1	1	1		1									11.19	7	78.3	187.60	.17
SAMPLE 9-- 12052			3	1	2	2	2										9.44	11	103.8	129.66	.22
SAMPLE 10-- 12061			367	15	1												1.10*	383	422.2	.70	.88
SAMPLE 11-- 12135				1													3.50	1	3.5	.00	.01
SAMPLE 12-- 12141			9	10	5		2										4.38	26	113.6	8.34	.24
SAMPLE 13-- 12142			8	12	5	8	3				2						6.72	38	255.3	27.26	.53
SAMPLE 14-- 12152					2												6.55	2	13.1	1.14	.03
SAMPLE 15-- 12161			43	13													1.75*	56	98.2	1.64	.20
SAMPLE 16-- 13110			13														.60**	13	7.8	.15	.02
SAMPLE 17-- 13130			40	10	1	2		1									2.12*	54	114.7	8.58	.24
SAMPLE 18-- 13140			5														.52**	5	2.6	.01	.01
SAMPLE 19-- 13150			26														.47**	26	12.2	.07	.02
SAMPLE 20-- 13151			1														.50**	1	.5	.00	.00
SAMPLE 21-- 13230			1														.20**	1	.2	.00	.00
SAMPLE 22-- 13231			84	5	3	3		1	2		2						2.23*	100	222.7	18.56	.46
SAMPLE 23-- 13310			14	2	1	1											6.86	19	130.3	331.30	.27
SAMPLE 24-- 13320			26	3		1	1	1									2.28	32	72.9	12.88	.15
SAMPLE 25-- 13330			71	12	7		1	1									2.14*	92	197.3	6.55	.41

Fig. 12 -- Analysis of variance break-rate computation

(If desired, a base-line (sortie count) may be read in providing a break-rate (demand rate for work center data) shown to the right under "Breaks". The base-line entry appears just above this following "Sorties--". The other entries are defined in Fig. 11.)

defined by the control card; for example, no fixed field location is required. Data records must, however, be identified by sample (major) and subsample (minor). Further, all data are edited with the decimal to the left of the first low-order position. The program edit assumes that all input data have hours and tenths of hours, yards and tenths, mach and tenths, for example. But whole numbers may be processed without decimal place confusion by punching any legal character in Col. 41 of the control card (format C2).

The program's versatility is constrained only by the user's agility in mentally sorting data into major and minor categories. For example, processing with a major on shop, a minor on action taken, and computing on man-hours will yield, for each shop and each action taken, the mean, totals, count, etc., enumerated. Majoring on shop and minoring on month will yield the beginning of trend evaluation. Majoring on tail number and minoring on write-ups yields the beginning of a sick bird isolation. In the latter, turning switch D "off" will produce a deck of input for the Chi-square program to obtain a more vigorous definition of sick birds.

Aircraft status is a typical summary that the Analysis of Variance program makes possible. Using program CET, select the status data (Col. 80=3) output by the Edit program (format Q). Sort majoring on squadron (Col. 79) and minoring on status code (Col. 26). The elapsed time data are located in Cols. 70-72 (in hours and tenths). The result will be a status summary for each squadron.

In the examples cited, we have ignored the F-test computation which tells us whether true differences exist among the means of the subsamples (i.e. the program has been used only to summarize data). In the following illustrations, the F-test is considered. The dependent variable is implied: man-hours, recovery time, write-up rate, mission success, etc. The program can be used, for example, to determine the effects of the type of mission flown, the type of ordnance carried, the work-shift that accomplished the maintenance, an extensive engineering modification, a procedure revision, and combat flying (compared with ZI flying). In all these comparisons, the F-test is

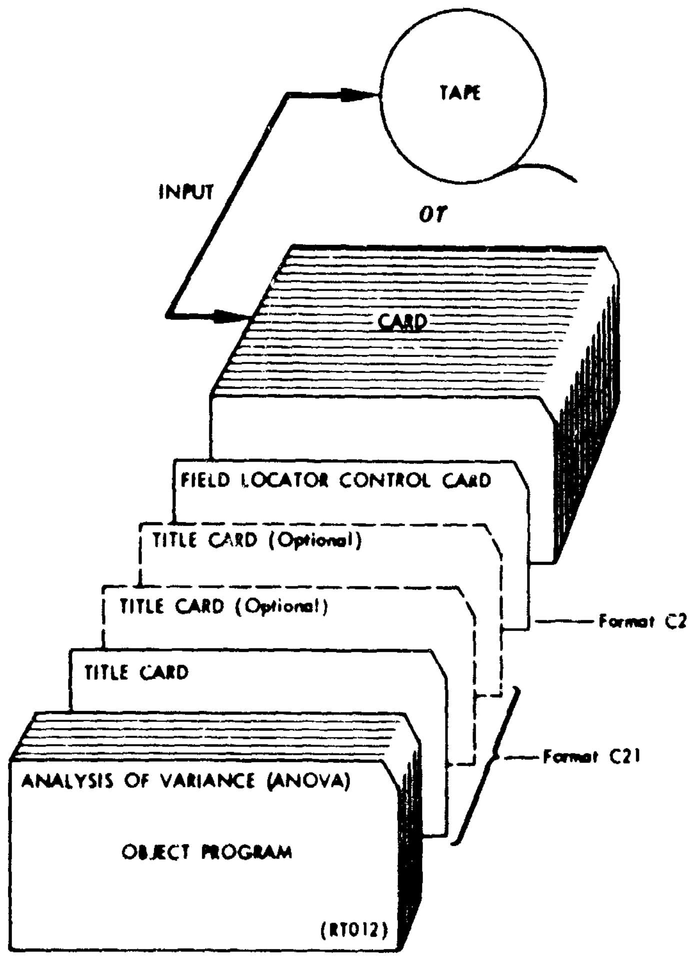

Fig. 13 -- Analysis of variance program setup

scrutinized to determine whether the different conditions are beyond that expected by normal (random) variation.

Switch action is as follows:

Switches I/O and A are always "on".

Switch B--"on" prints break average
"off" prints break-rate.

Switch C--"on" card input.
"off" tape input (mount input tape on unit 2).

Switch D--"on" eliminates punching
"off" punches inputs to Chi-square (format X).

Switch E--"on" excludes zero data from computations.
"off" includes zero data in computations.

Switch F--not used

Switch G--"on" terminates tape processing (i.e., end of job).
"off" no action.

A scratch (work) tape must be mounted on unit 6 for all processing.

Prior to processing, data must be sorted by major and minor. The program allows printing of three title cards (format C21). Refer to format C2 for punching the field locator control card. A printout of the tape input data can be produced by punching the desired number of pages to be printed in Cols. 6-7 of the control card (format C2). To produce the break average or break-rate computations, the sortie count must be punched in Cols. 1-4 of the control card.

Chi-Square

The Chi-square program is used to make statistical comparisons among frequency data.* It computes Chi-square for both dichotomous and non-dichotomous data, and computes an approximated probability (alpha) level as well. To help isolate items causing non-homogeneity of the data, each observed frequency is tested against its expected frequency. If the test indicates an alpha level beyond 0.05, 0.01 or 0.001, it is appropriately tagged. The observed frequency means are averaged to obtain an unweighted grand mean, converted to Z-scores, and plotted as a distribution around the unweighted mean. This distribution is shown to the right of the Chi-square computations in Fig. 14.

Since analyses frequently involve computing a sequence of Chi-squares, the program can process stacked samples. As with Analysis of Variance, a change in the major field indicates a new sample. Unrelated samples, for instance those that differ in format, or those that would not be subsumed under a given title, may be stacked by using new title and control cards. The program senses Col. 80 to determine whether the record is a title card (format C15) or control card (format C16).

The program requires four items.

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*See Sweetland, ibid., on the use of Chi-square for analyzing maintenance data.

SPANGDAHLEM AFB F-105 WRITE-UPS PRO-RATED BY SORTIES FLOWN AIRCRAFT -MAJOR-

	BASE-LINE	FO	FT	D2/FT	MEANS	-3	-2	-1	0	1	2	3	4	5
	34	34	43.19	1.96	1.000		.	AAR	.		.		.	
	27	48	34.30	5.47*	1.778		.		.	ABT	.		.	
	40	59	50.82	1.32	1.475		.		C/S		.		.	
	46	54	58.44	.34	1.174		.		CAS.		.		.	
	3	6	3.81	1.26	2.000		.		.	CHA	.		.	
	101	108	128.31	3.22	1.069		.	CNV	.		.		.	
	3	2	3.81	.86	.667		.	CWX	.		.		.	
	21	15	26.68	5.11*	.714		.	DRT	.		.		.	
	4	3	5.08	.85	.750		.	EVA	.		.		.	
	103	286	130.85	183.96***	2.777		.		.		.	FCF	.	
	6	4	7.62	1.72	.667		.	GAR	.		.		.	
	133	206	168.96	8.12**	1.549		.		GND		.		.	
	78	86	99.09	1.73	1.103		.		NIT.		.		.	
	63	73	80.04	.62	1.159		.		NUC.		.		.	
	2	3	2.54	.08	1.500		.		TRA		.		.	
	189	282	240.11	7.31**	1.492		.		X/C		.		.	
	752	770	955.34	35.96***	1.024		.	51-	.		.		.	
TOTAL	1605	2039												

WEIGHTED GRAND MEAN-- 1.270 1.288 -UNWEIGHTED-
CHI-SQUARE-- 259.88

DF-- 16

THE CHI-SQUARE IS QUESTIONABLE. CHECK FT FOR ENTRIES OF 5.0 OR LESS.

THE PROBABILITY IS BEYOND THE 0.001 LEVEL. THE DISTRIBUTION IS NOT HOMOGENEOUS.

Fig. 14 -- Chi-square

(The major is the upper right code. The minors (general 3-character) are shown in the distributions. The conventional chi-square computations appear under the headings "FO" (observed frequencies), "FT" (theoretical frequencies), "D2/FT" (FO-FT squared and divided by FT) and the means (FO divided by the base-line). One, two, or three asterisks indicate the cell entry was tested and fell beyond the 5-, 1-, or 0.1-percent levels, respectively. Entries in the means columns are converted to Z scores and distributed around the unweighted sample mean in the display on the right.)

1. The base-line. This is used to compute the theoretical frequencies. In maintenance analysis, the base-line data are a count of the times an event was attempted. Most frequently, this is a count of the sorties flown in each category or condition. Other base-line frequencies are number of intercepts attempted, number of rounds fired, number of target passes, and so on.

2. The observed frequency. This is generally a count of the successes or failures. Typical are number of write-ups, number of kills, number of dud bombs, number of aborts or deviations, number of demands, and so on.

3. The category identification. This is used only to display the distributions. It is generally three characters, the center character locating the Z-score conversion. The categories most frequently used will be tail numbers (last three or four digits as may be necessary to identify aircraft in the analysis), sortie types and months (for trend determination). It is best to pad out one- and two-character identifiers to three characters since the center character functions as the Z-score locator.

4. The major sense. A change in this field initiates processing of the next sample. Any field that identifies the sample may be used. The major identifies the sample in the printout, and also sorts the data. The major sense is used when one title card is appropriate to several samples (see switch C settings). Notice that no minor sort is required, although it is frequently helpful to pre-sort by category identification. It is also sometimes helpful to pre-sort data by base-line (order by frequency of exposure) or by observed frequency (order by frequency of failure). The distributions of the means resulting from these latter two pre-sorts may suggest possible non-linear relationships between base-line and the observed frequency.

The user will quickly discover that the sample units (n's) produced by the Analysis of Variance program are often used as observed frequencies for Chi-square computations. To take advantage of this, the Analysis of Variance program has a switch action that produces the Chi-square data input deck; the user, however, must add the base-line data. The base-line is generally unknown when the analysis of variance is computed. The following sequence resolves this problem.

Assume the analyst wants to measure the impact the sortie type has on system recovery and break-rates. First, using the 2-digit system recovery file (format R2), he must run the Analysis of Variance program minoring on sortie type and majoring on system (Col. 2-8). This will produce the system recovery analyses plus a deck for the Chi-square computations. Next, using the aircraft recovery file (format R1), he must determine the number of sorties flown for each type of mission, and punch this number into the appropriate cards of the Chi-square input deck. Processing with Chi-square in this manner would yield the system break-rates tested for non-homogeneity.

The user must remember that the methods differ for computing Chi-square from dichotomous (break-rates and demand rates) and from non-dichotomous data (write-up rates and units produced). The dichotomous method always includes computations based on the non-occurrence frequencies; the non-dichotomous method never includes these computations.* Switch action controls the inclusion of the non-occurrence computations. Set switch D "off" when computing dichotomous data and "on" when computing non-dichotomous data.

Since the input data are derived, there is no direct data source for the Chi-square program. More often than not, the input deck will result from judicious selection of Analysis of Variance testing. Because the FREQ program described below is designed specifically to provide frequency counts of categories, it is ideally suited to provide inputs to the Chi-square program.

One or more title cards (format C15) may be used. When one title is used, the computer senses for a change in the major field to produce a summary. If several titles are used, a separate format card (format C16) must describe each sample. Thus one can stack several related samples behind a general title and control card, or can also stack separate, nonrelated samples, each having its own title and control card. See Fig. 15 for the Chi-square program setup

The following switch actions apply:

Switches I/O and A are always "on".

Switch B--"off" for card.
"on" for tape input; tape on unit 1.

Switch C--"on" when only one title and control card are used.
"off" when each sample has its own title and control card. When C is "off", data must be sorted by major.

Switch D--"on" when computing nonbinomial data.
"off" when computing binomial data.

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*Ibid.

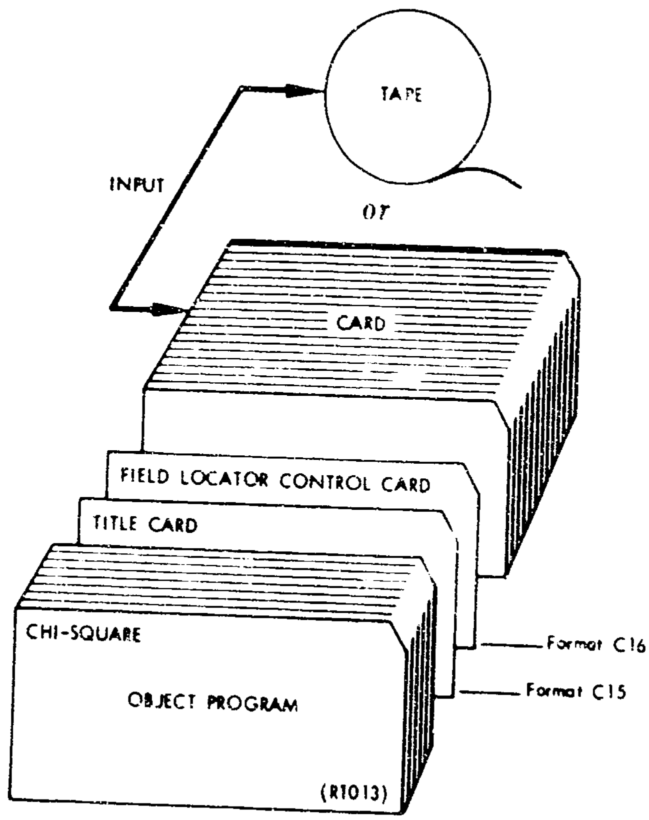


Fig. 15 -- Chi-square program setup

Frequency Counter (FREQ)

The Frequency Counter program (FREQ) searches any field of unknown and unsorted data, builds a table, and counts the frequency entries in the field. For example, assume a deck of sortie deviation data coded by type of deviation: GND-ground abort, AIR-air abort, BUD-buddy abort, and so on. The program determines not only which codes occur in the field, but also how frequently they occur, as shown in Fig. 16. The field may have as many as three separate subfields--major, intermediate and minor--located in separate parts of the record. The sum of the columns of the three subfields must not exceed 12. The program starts with a "blank" table. As each record is read in, the computer asks "Do I have this code in my table?" If not, it adds the new code.

FREQ is principally used to obtain rapid preliminary estimates of an unknown phenomenon to serve as a basis for more formal

TWO-DIGIT SYSTEM COUNT -- TAPE T2 DECK 1

FIELD 46- 47

01	3484	.321
03	1211	.111
02	64	.006
04	1394	.128
11	866	.080
74	777	.072
13	504	.046
71	448	.041
91	24	.002
51	99	.009
12	202	.019
42	100	.009
44	76	.007
14	291	.027
06	52	.005
45	252	.023
07	48	.004
73	66	.006
52	141	.013
75	174	.016
09	41	.004
41	139	.013
46	139	.013
23	120	.011
76	33	.003
49	19	.002
77	3	.000
47	47	.004
93	20	.002
05	1	.000
72	21	.002
61	2	.000
96	1	.000
08	1	.000
69	1	.000

RECORDS - 10861

Fig. 16 -- Output sample of FREQ

(The low- and high-order positions of the field being searched are shown to the right of the word "FIELD". The field entries discovered by the program are given in the left-hand column and the corresponding record counts in the middle. Total record count is given to the right of "RECORDS".)

exploration. In this instance, the end-sample (asterisk) card can be quite useful in establishing tentative samples, e.g., first week, second week, third week, and so on. The program is also used to obtain observed frequencies for Chi-square computations. Other uses are to obtain the following: the tables used by Clint (2-digit system and work center), counts of sortie deviations, bench check actions, types of sorties flown, and how-mal actions. Since most maintenance data are nonquantitative (categorical), there is no shortage of opportunities to use the program.

Either card or tape input may be used. If desired, the program will generate a deck of cards (format Z) containing the code (Cols. 13 to 27) and the frequency of occurrence (Cols. 8 to 12), with one code per card. This deck, reformatted, may be used as an input table to the programs requiring it--the Error Edit and Clint.

In using FREQ, it is unnecessary to sort input data. In fact, one main reason for writing this program is to avoid the need for sorting. Frequency counts of sorted data may be obtained by using analysis of variance.

Any number of samples may be stacked if card input is used, but only if the same field is to be searched in all samples. The samples must be separated by a card containing an [illegible]-4-8 punch in Col. 1 (format C19). All samples should be titled by punching the appropriate descriptions in Cols. 19-79 of the control card (format C14).

The following switch actions apply:

Switches I/O and A are always "on".

Switch B--"on" for tape input; mount tape on unit 1.
"off" for card input.

Switch C--"on" to punch a deck of table entries with associated frequencies.

Switch E--"on" if a specific card code (Col. 80) is to be selected.

Switch G--"on" when last input tape has been processed.

The remaining switches are always "off".

The control card locates the field or fields to be counted. The high-order position of the major is punched in Cols. 1-3, the low-order

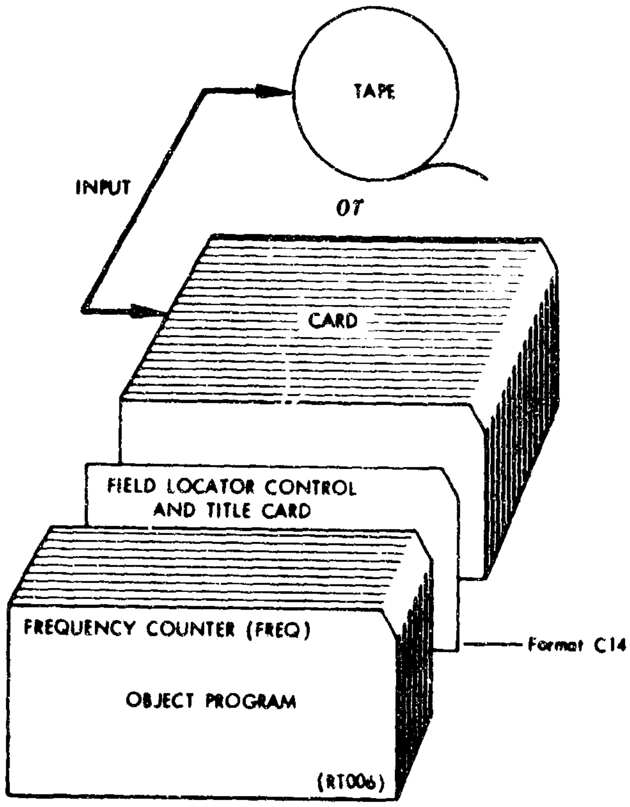


Fig. 17 -- Frequency counter program setup

position in Cols. 4-6. The corresponding positions of the intermediate are punched in Cols. 7-9 and 10-12, respectively. The minor positions are punched in Cols. 13-15 and 16-18. The field positions must be preceded with zeros; blanks are unacceptable. If a specific card type coded in Col. 80 is to be selected from a sample of mixed formats, punch the desired card code in Col. 80 of the control card. Columns 19-79 of the control card may be used as a title.

Correlation Matrix

The Correlation Matrix program handles a maximum of twelve variables, producing a matrix of Pearson Product-Moment correlations. The program keeps count of data greater than zero and produces two sets of means and standard deviations: one based on all of the records, and the other based only on data greater than zero. These two sets show

how missing data distort the correlations by calculating only on xy pairs greater than zero.

Although there is no limit to sample size, we discourage the use of samples greater than 500. When sample sizes exceed this, it is better to break them into two or more random groups, and cross-validate the results.

By switch option the program also provides a test for questionable "dependent" variable prediction by tagging those intercorrelations of independent variables that are greater than the correlations with the dependent variable. All twelve variables may be designated as "dependent."

The Correlation Matrix program requires a number of control cards as shown in Fig. 18.

1. Title card (format C18). This must have a 0-3-8 punch in Col. 1. The remaining columns may be used as a title.

2. Field designation cards (format C17). Up to twelve are used. These locate the left- and right-hand boundaries of the fields. One card is used for each variable. Columns 1-2 contain the variable numbers 1 through 12 preceded by zeros. Column 3 is left blank. Columns 4-9 (6 digits) are used as titles for each field. These titles are preferably right-adjusted if fewer than six characters. Column 10 is left blank. Columns 11-13 locate the left-hand (high-order) position of the field. Columns 14-16 locate the right-hand (low-order) position of the field. Precede with zeros.

   All data are assumed rounded to one decimal place (e.g., hours and tenths, angles and tenths). When processing whole numbers, circumvent this by punching any entry in Col. 18 of the field definition cards; for example, "SHIFT LEFT ONE POSITION". The program then shifts the data one position to the left before processing.

3. A card with an 11-4-8 punch in Col. 1 (format C19) terminates the loading of the field definition table.

4. If the test for questionable independent variables is included, use a card with a 3-8 punch in Col. 1 (format C20). In Cols. 2-3, 4-5, 6-7, etc., punch and precede with zeros the number of the dependent variables to be used; for example, a 03 punched in Cols. 2-3 indicates that the data are to be tested against the third variable.

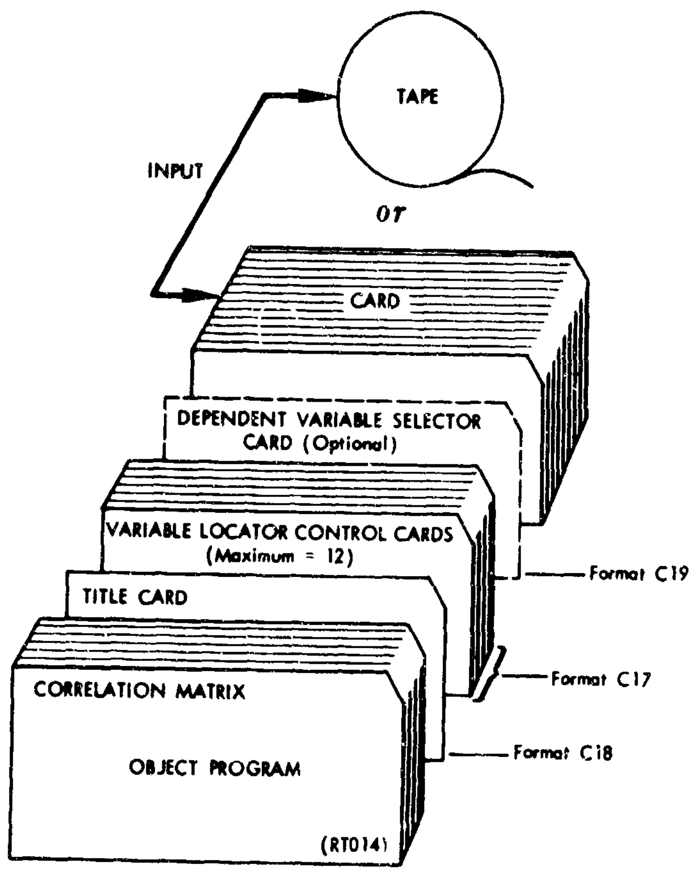


Fig. 18 -- Correlation matrix program setup

The following switch actions apply:

Switches I/O and A are always "on".

Switch B--"on" for card input.

Switch C--"on" for tape input. Tape on unit 1.

Switch E--"on" omits zero (no entry) variables from calculations.

Switch G--"on" omits printout of dependent variable tests.

Deviation-Degradation (DEVDEG)

This is a special purpose program for listing the mission deviation-degradation data from the 308 forms. The only data acceptable are the form 308 edit outputs (format U).

Using CET, select the edited data by punching "H" in Col. 3 of the control card. Sort by deviation code.

DEVIATION AND DEGRADATION ANALYSIS

TAIL	DATE	HRMN	W/U/C	SYM	-CALL-		
0838	1201	1840	4154A	AIR	WASP	T E FLAP BARBER POLES AT 310 KNOTS	
0839	1801	2110	41500	AIR	NATE	BLC LITE ON TAKE OFF	
7687	0109	1110	41000	AIR	NICK42	SMOKE IN COCKPIT	
7710	0809	1840	71400	AIR	CHICAG	INS PROBLEM/NO SPARE	
0735	2010	0900	23000	AIR	KODAK	AUX AIR DOOR OPEN	
0819	0210	1815	14000	AIR	KNIFE	FLIGHT CONTROL VIBRATIONS	
7500	1309	2020	45000	AIR	HUDSON	CENTER LINE TANK DOES NOT FEED	
							7
7645	1909	1850	11000	BUD	LOVER		
7650	3008	2040	11000	BUD	KODAK	SYMPATHY WITH 7710	
7650	1509	1940	11000	BUD	ROSCO	SYMPATHY FOR 7687	
7641	2508	2035	11000	BUD	HURRIC	SYMPATHY WITH 7687	
7642	1808	0001	11000	BUD	FALCON	SYMPATHY ABORT	
7586	2608	1730	11000	BUD	MIDGET	SYMPATHY ABORT	
						SYMPATHY ABORT	
							6
7522	0412	0230	23000	GND	ACORN	HIGH OIL PRESS NO =2 ENG 0927 SPARE	
7442	1212	2035	51000	GND	BUICK	NO POWER TO ATTITUDE INDICATOR SPARED 7499	
7623	2212	1330	46000	GND	SWORD	DUE TO C/L TANK LEAK SPARED BY 0842	
7532	0310	0630	46000	GND	OMAHA	NO BOOST PUMP PRESSURE	
7496	2210	0740	23000	GND	DEVIL	FUEL LEAK IN ENGINE COMP	
7496	0810	1015	74000	GND	VEGAS	RADAR INOP	
0720	1108	1305	13400	GND	MAMBON	LH BRAKE LOCKED ON TAXI ROLL	
0720	0708	1240	12350	GND	RIG	COULD NOT CLOSE AFT CANOPY	
0720	2308	0700	46000	GND	VESPA	LT DROP TANK LEAKING	
0720	1009	1425	1325D	GND	GATOR	BLEW RT MAIN TIRE	
0779	0909	0415	13440	GND	ZIPPER	LEFT BRAKE LOCKED ON TAXI	
0779	2109	2055	13000	GND	FRESNO	RUDDER FLUTTER	
							12
7650	1209	1245	11000	HHQ	CLIPPE		
7645	2808	1720	11000	HHQ	ROSCOE	TAKE OFF TIME DELAY 20 MINUTES	
7642	0808	1445	11000	HHQ	VESPA	TIME CHG DELAY 40MIN	
7642	1708	0530	11000	HHQ	MUSKRA	CANCELLED BY HIGHER HEADQUARTERS	
7641	1809	1935	11000	HHQ	ROSCOE	TIME READJUSTED TO 0630	
7680	1709	2030	11000	HHQ	DOBE	LATE DUE TO CENTER LINE TANK LOOSE	
						LATE TAKE OFF DUE TO ABORT OF 7586	
							6
7640	2308	1750	46000	MND	BUCKSH		
7626	1109	2030	23000	MND	CLIPPE	RT TANK WONT TAKE FUEL	
7643	2808	1325	41500	MND	SWORD	OIL LEAK&NO SPARE	
7686	2109	0410	74000	MND	WINDSO	BLC LITE CAME ON	
7687	2608	2155	75000	MND	HUDSON	BOTH SCOPES BLANK	
7442	0701	1145	11000	MND	DUTCH	ACFT NOT LOADED	
0841	2312	1355	01480	MND	RIP	NO ACFT AVAILABLE	
7710	1909	1850	74000	MND	LOVER	TANK CHANGE	
						CENTER LINE BREACH STRIPPED	
							8
7659	1409	0430	11000	OPS	CLEVEL	CANX BY COL CLARK	

Fig. 19 -- DEVDEG (deviation and degradation) output

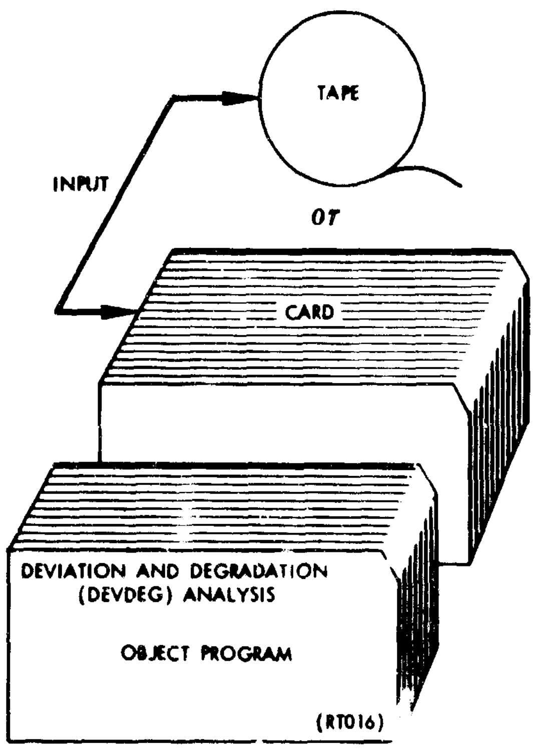


Fig. 20 -- Deviation-degradation program setup

Major	Cols.	7-8	AN
Minor	Col.	17	AN

If separation by system code is desired, presort by system code (Col. 46-50 AN). It is also possible to separate data by month, squadron or tail number, and so on, by post-sorting on the appropriate field.

No control cards are used. Switches I/O and A are "on" for tape data, and switches I/O, A, and B are "on" for card data.

III. NEW DEVELOPMENTS

To this point, the text has described a fairly well developed methodology. The techniques have been used in various situations over a period of years, and the programs have been continually modified through these experiences. Hence, the system described thus far is fairly well shaken down. For the Rapid Roger project, however, we investigated an area where we had little prior experience--that of resource allocation, in which resources were defined as personnel, equipment, and supply. This section describes several additions to the daily package for dealing with resource allocation problems. The reader is cautioned that these are first trials, which themselves are still being shaken down.

THE MANPOWER UTILIZATION SEQUENCE

Although the Manpower Utilization Sequence is a general purpose program, we will first discuss it as a special purpose program. The sequence relates personnel utilization (direct, on-equipment labor) to sorties flown. Utilization is shown by shop across the 24-hour period. Three data elements are used and described below: maximum number of personnel used, number of personnel available, and touchdowns. Each element is first displayed in both detail and summary form for each work center. On the last page for each work center, the summary data are repeated along with computations of utilization rates. To simplify this description, it is assumed that the data are selected for the period to be tested. Assume that one tape is used each day.

Manpower Utilization

Place the following control card (format C12) behind the Hourly Frequency Accumulate (HFA) program.

Cols. 1-6	062066
Cols. 7-12	026026
Col. 79	N
Col. 80	0 (numeric)

Mount the work center daily display tape on unit 1. Set switches I/O, A, B and C "on", and repeat for each day's tape. The program searches each minute of the hour to find the number of men working each minute. When the computer senses a change in the day or in the work center, it produces a summary card for that work center day (format W). This card contains entries showing the largest number of men used each hour. The computer tests each minute of each hour and retains the largest entry. The program also accumulates the man-hours for the work center. The output deck, identified by an "N" in Col. 80 (format W), is retained for further processing.

Manpower Available

Place the following control card (format C13) behind the Compute Elapsed Time program and mount the tail-number daily-display tape on unit 1.

Cols. 1-3 OIE

Set I/O, A and D "on", and repeat for each day's tape. The program selects the manpower availability data (format W), and produces a summary card showing the number of men available for each hour of each work-center day. This deck, also retained, has an "E" in Col. 80.

Touchdown Counts

The last summary needed is a card for each day showing the number of touchdowns for each hour of that day. Place the following control card (format C13) behind the Compute Elapsed Time (CET) program.

Cols 1-3 012

Mount the tail number display tape on unit 1. Set switches I/O, A and D "on", and repeat for each day's tape. This will select the sortie cards.

Combine the across-midnight cards using program S/F/L. To do this, maintain the sorting integrity. Set switches I/O and A "on". Save the output, destroy the input. Inspect the last day of this sample and remove any cards containing 2400 in Cols. 21-24. These are false touchdowns: the first record of the across-midnight sortie "lands" at 2400 hours.

If the sorting integrity has been disrupted by removing the 24-hour touchdowns, resort the deck.

Major	Cols. 11-12	N month
Minor	Cols. 9-10	N day

Place a control card (format C12) behind Hourly Frequency Accumulate, as shown in Fig. 21.

Cols. 1-6	009012
Cols. 7-12	blank
Col. 79	[illegible]
Col. 80	2

Set switches I/O, A and C "on". The output is the count of the landings during each hour of the day for each day of the period (format W, Col. 80=A). Destroy the input.

Utilization Display

We now have three sets of records containing summaries for each hour of the day for each day of the period:

1. The 24-hour manpower utilization records showing the largest number of men used hourly by each work center (Col. 80=N).
2. The 24-hour manpower availability records showing the number of personnel available hourly for assignment from work center (Col. 80=F).
3. The 24-hour touchdown records showing the hourly potential demands on each work center (Col. 80=A).
4. If desired, the off-equipment man-hours may be added to this display by punching up a summary card for each work center day:

Cols. 1-5	work center
Cols. 6-7	day
Cols. 8-9	month
Cols. 59-64	man-hours (in hours and tenth-hours)
Col. 80	V

These three decks, shown in Fig. 22, are combined and sorted as follows:

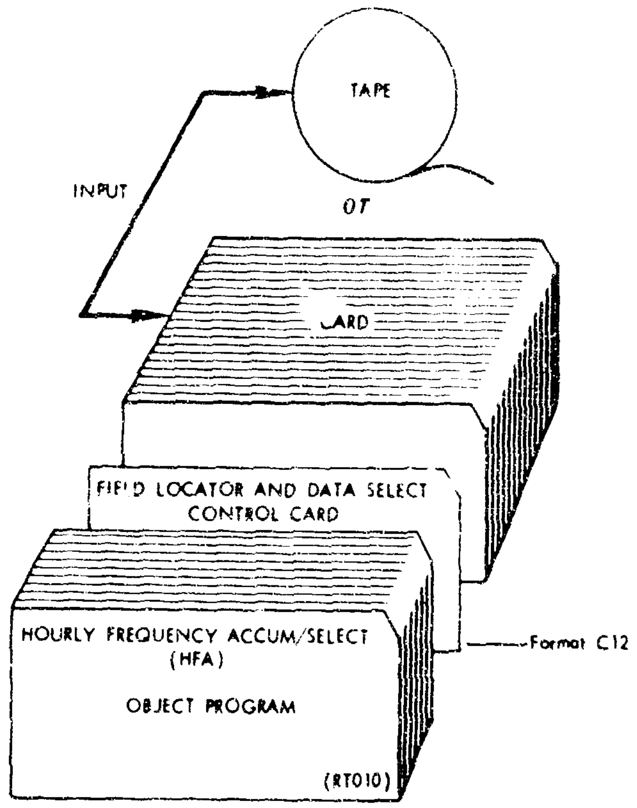


Fig. 21 -- Hourly frequency accumulate and select program setup

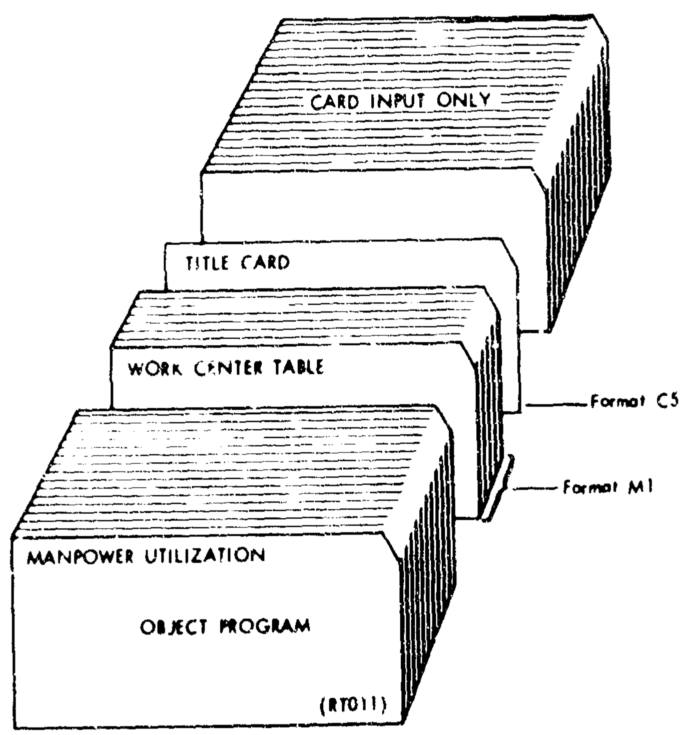


Fig. 22 -- Manpower utilization program setup

Major	Cols. 1-5 AN	work center
↓	Col. 80 A	card type
	Cols. 8-9 N	month
Minor	Cols. 6-7 N	day

The deck is now ready to produce the final report. Place the table of legal work centers (format M1) b ind the Manpower Utilizatic program. Follow this by the manpower utilization title card (format C5) and the data sorted as indicated. Set switches I/O and A "on".

Manpower Matrix

The Manpower Matrix program, a simplified 1401 version of a 7044 program (see Sec. IV: Sequential Frequency Distributions), provides another method of displaying summary data created by the Hourly Frequency Accumulate/Select program. The sample Manpower Matrix printout used the same set of manpower utilization processed by the Manpower Utilization program.

The manpower matrix printout was created by sorting the input file to the Manpower Utilization program to select all cards with Col. 80=N. The selected deck, Fig. 23, was preceded by a title card (format C5), punched with the data range of the data included in the sample, placed

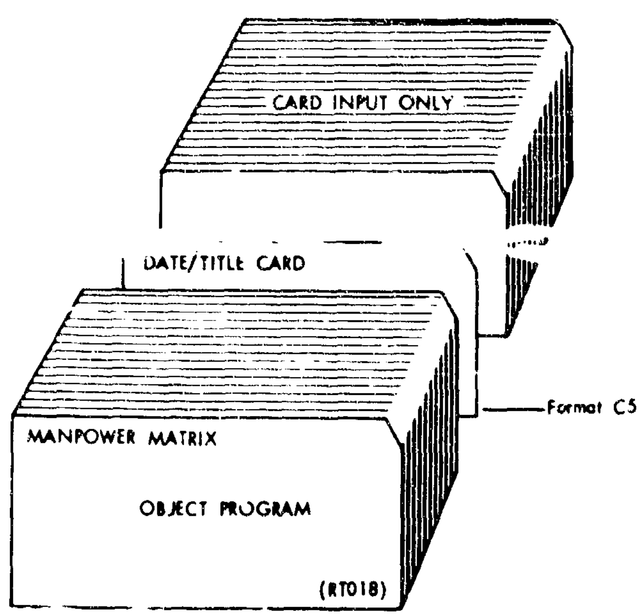


Fig. 23 -- Manpower matrix program setup

behind the Manpower Matrix program, and processed with switches I/O and A "on". The output for the complete sequence is shown in Figs. 24 through 28.

To this point, we have discussed the utilization sequence as a special purpose manpower utilization analysis. The following describes how it may be used as a general purpose sequence. Note that the Hourly Frequency Accumulate program generates two kinds of data: (1) touchdown frequencies and (2) utilization-availability frequencies. The first is characterized as a single time entry event (zero time-duration), the second as a double time entry event (start and stop time). Note further that all data in Oxnard formats fall into one of these two categories. Therefore, all Oxnard formats can be converted to the W format for similar analysis. This conversion is made possible by the frequency field selector control card (format C12) used with the Hourly Frequency Accumulate program.

In format C12, the location of the minor sense (work center in the example) is punched in Cols. 1-6. A change in this field produces a summary card. Had the program been used to summarize aircraft status, the status code location (Col. 26) would have been used. The frequency count location is punched in Cols. 7-12; this is generally team size (Col. 26). If this field on the control card is left blank, the frequency count is automatically set to "1". The card code (Col. 80 of the W format) desired is entered in Col. 79 of the control card. These codes control the output sorting sequence: to correspond with the previous sequence, use only codes A, E, and N, which the Manpower Utilization program senses. Column 80 of the control card shows the Oxnard card code to be selected.

Before processing single-entry data such as sorties scheduled or aborts, the records must be duplicated to reproduce the contents of Cols. 9-16 in Cols. 17-24. This moves the time entries into the proper field (touchdown time field) for processing through the touchdown sequence. Thus the program makes it possible to display (singly or in combination) any clock-hour information. The ACE utilization data are the first logical candidates. Sorties scheduled versus sorties flown are another. Delay codes related to sorties scheduled and sorties

DAILY SORTIE TOUCHDOWNS, BY HOUR, FOR MONTH 01 — SAMPLE - MANPOWER UTILIZATION

DATE	[illegible]	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	[illegible]
09/01				2	3	1		4	1	4	2	1		1	1		4	3		3	3		6		[illegible]
10/01	2			2	4	2			2	5	3			2	4	7				2	2	4		2	[illegible]
11/01	4	2		2	6			6		3			5			9		1	2	2		4	2	4	[illegible]
12/01		4			7	1		4	2	[illegible]	4		2		2	4	4	1	2	4			3	4	[illegible]
13/01		1	4	1		2		6	1		3	2	3		2	4	5		4	6	1	1	2		[illegible]
14/01	1	3			2	6		4	3	4				3	2	[illegible]	2		1	1	2	6		2	[illegible]
15/01		4		4	4			4	2	4	1	2	2		2	9		1	3		4		5	4	[illegible]
16/01				4	4	2			3	7			2		6	3				4		4	4		[illegible]
17/01	2		3	2	[illegible]	3		4	2	3		2	3	3	2	6		1	1	4	2	2	2	2	[illegible]
18/01	2	2	4	2		4		4	2	4			1	2	2	7		1		4	2	4			[illegible]
TOTAL	11	16	11	19	14	21		36	18	36	13	7	18	11	23	57	15	8	13	30	16	25		18	[illegible]
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	1	0	21	22	23	24	

1.10 1.10 3.-0 1.80 1.30 1.80 2.30 1.50 1.30 1.60 2.40

1.60 1.90 2.10 3.60 1.60 .70 1.10 5.70 .80 3.00 2.50 1.80

Fig. 24 -- Manpower utilization: touchdown summary

(Touchdowns are shown for each hour of the day at the end-hour--the midnight to 0100 counts appear under "1". One line is given for each day, with the touchdowns per hour under "AVG" on the right. At the bottom are the count totals for each hour. These totals are divided by the number of days to give the averages for each hour of the day. Note the wide variations in the daily counts, particularly from 1100 to 1700 hours.)

DAILY MANPOWER AVAILABLE, BY HOUR, FOR MONTH 01 SAMPLE - MANPOWER UTILIZATION

WORK CENTER 12041 TESTSQ FLIGHT LINE FLIGHT =A SECT I

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	AVG
09/01	14	14	14	14	14	14	14	14	14	14	14	14	14	14	[illegible]	14	10	10	10	10	10	10	10	10	12.66
10/01	14	14	14	14	14	14	14	16	16	16	16	16	16	16	[illegible]	16	10	10	10	10	10	10	10	10	13.41
11/01	14	14	14	14	14	14	14	14	14	14	14	14	14	14	[illegible]	14	10	10	10	10	10	10	10	10	12.66
12/01	13	13	13	13	13	13	13	16	16	16	16	16	16	16	16	16	11	11	11	11	11	11	11	11	13.45
13/01	13	13	13	13	13	13	13	15	15	15	15	15	15	15	15	15	13	13	13	13	13	13	13	13	13.75
14/01	13	13	13	3	13	13	13	16	16	16	16	16	16	16	16	16	12	12	12	12	12	12	12	12	13.79
15/01	13	13	13	13	13	13	13	15	15	15	15	15	15	15	15	15	11	11	11	11	11	11	11	11	13.08
16/01	14	14	14	14	14	14	14	15	15	15	15	15	15	15	15	15	11	11	11	11	11	11	11	11	13.37
17/01	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	11	11	11	11	11	11	11	11	12.33
18/01	14	14	14	14	14	14	14	12	12	12	12	12	12	12	12	12	11	11	11	11	11	11	11	11	12.25
TOTAL	35	135	135	135	135	135	135	146	146	146	146	146	146	146	146	1.6	110	110	110	110	110	110	10	110	13.07

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

13.50 13.50 13.50 13.50 14.60 14.60 14.60 14.60 11.00 11.00 11.00 11.00

13.50 13.50 13.50 14.60 14.50 14.60 14.60 14.60 11.00 11.00 11.00 11.00

Fig. 25 -- Manpower utilization: manpower available

(The entries, [illegible] ges and summaries follow the same format as Fig. 20. The data show that availability is low in the "B" shift, [illegible]30-1630 hours, and high in the "C" shift, 1630-2400 hours.)

DAILY MANPOWER UTILIZED, BY HOUR, FOR MONTH 01 SAMPLE – MANPOWER UTILIZATION

WORK CENTER 12C41 TESTSQ FLIGHT LINE FLIGHT =A SECT 1

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	AVG
09/01	3	6	7	5	4	5	4	15	10	[illegible]	3	8	5	6	11	7	4	9	6	9	10	5	9	9	7.00
10/01	4	3	9	9	8	7	5	11	9	12	7	10	6	6	9	9	8	6	6	8	7	7	6	8	7.50
11/01	6	8	12	3	4	6	8	13	10	11	9	15	9	10	9	7	8	9	4	9	5	4	7	6	8.00
12/01	9	5	6	10	7	9	13	5	14	15	8	7	11	15	10	14	12	13	8	9	8	8	10	8	9.54
13/01	12	5	8	12	8	7	5	11	11	7	15	10	8	11	10	4	6	8	9	3	8	3	9	4	8.08
14/01	4	5	2	3		11	12	8	10	11	9	9	7	6	9	9	13	14	11	4	4	7	5	3	7.75
15/01	7	7	4	1	3	8	5	13	8	15	14	11	14	15	11	9	12	7	8	12	3	[illegible]	[illegible]	7	8.54
16/01	9	11	10	5	6	15	12	9	14	20	13	12	10	10	10	11	17	10	5	3	8	5	9	8	10.12
17/01	8	7	3	10	11	8	11	18	21	16	8	10	7	13	6	12	9	5	5	8	7	10	6	6	9.37
18/01	14	11	9	8	3	6	8	10	10	11	8	8	3	8	8	11	14	9	6	6	7	7	6	3	8.08
TOTAL	76	68	70	66	49	82	83	113	117	126		100	80	100	93	93	103	90	68	76	72	63	72	62	8.40
	1	2	3	4	5	6	7	8	9	10	1	12	13	14	15	16	17	18	19	20	21	22	23	24	
	7.60	6.80	7.00	6.60	4.90	8.20	8.30	11.30	11.70	12.60	9.40	10.00	8.00	10.00	9.30	9.30	10.30	9.00	6.80	7.60	7.20	6.30	7.20	6.20	

Fig. 26 -- Manpower utilization: manpower utilized

(Format is the same as in Figs. 20 and 21. Note that the detail shows the largest number of men at work during each hour, not the largest number of teams.)

WORK CENTER -1?0?- AVERAGES AND UTILIZATION RATES FOR MONTH 01 SAMPLE - MANPOWER UTILIZATION

TESTSQ FLIGHT LINE FLIGHT A SECT I

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
TOUCHDOWNS -AVG-	1.10	1.60	1.13	1.90	3.40	2.10		3.60	1.80	3.60	1.30	.70	1.80	1.10	2.30	5.70	1.50	.80	1.30	3.00	1.60	2.50	2.40	1.80
AVAILABLE -AVG-	13.50	13.50	13.50	[illegible].50	13.50	13.50	13.50	14.60	14.60	1[illegible].60	14.60	14.60	14.60	14.60	14.60	14.60	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
UTILIZED -AVG-	7.60	6.80	7.0	6.60	4.90	8.20	8.33	11.30	11.70	1[illegible].60	9.40	10.00	8.00	10.00	9.30	9.30	10.30	9.00	6.80	7.60	7.20	6.30	7.20	6.20
UTIL RATE	.56	.50	.52	.49	.36	.61	.61	.77	.80	.86	.64	.68	.55	.68	.64	.64	.94	.82	.62	.69	.65	.57	.65	.56

DATA DAYS THIS MONTH

FLYING -	10
AVAILABLE -	10
WORKING -	10

TOTAL SORTIES -	480
FORM 300 TOTAL MANHOURS -	1,293.1
MANHOURS PER SORTIE -	2.7
AFTO 211 TOTAL MANHOURS -	2.2
AVAILABLE MANHOURS -	3,139.0
AVG MANHOURS UTIL -	.41

AVG PERS UTIL - .64

Fig. 27 -- Manpower utilization: summary

(The **average per hour summaries** from the bottoms of Figs. 23, 24 and 25 are repeated to aid the cross-comparison. The **entries** to the right of "Util Rate" are computed by dividing the utilized averages by the corresponding available averages. These utilization rates are summed and divided by 24 to give an unweighted average across the clock. Note that the highest utilization rates occur during the "B" shift, which has the lowest availability. The entries under "Data Days" show the sample sizes. For this particular output, the off-equipment man-hours were added (AFTO211...) to the form 300 totals and an overall utilization rate computed by dividing the total used by the total available.)

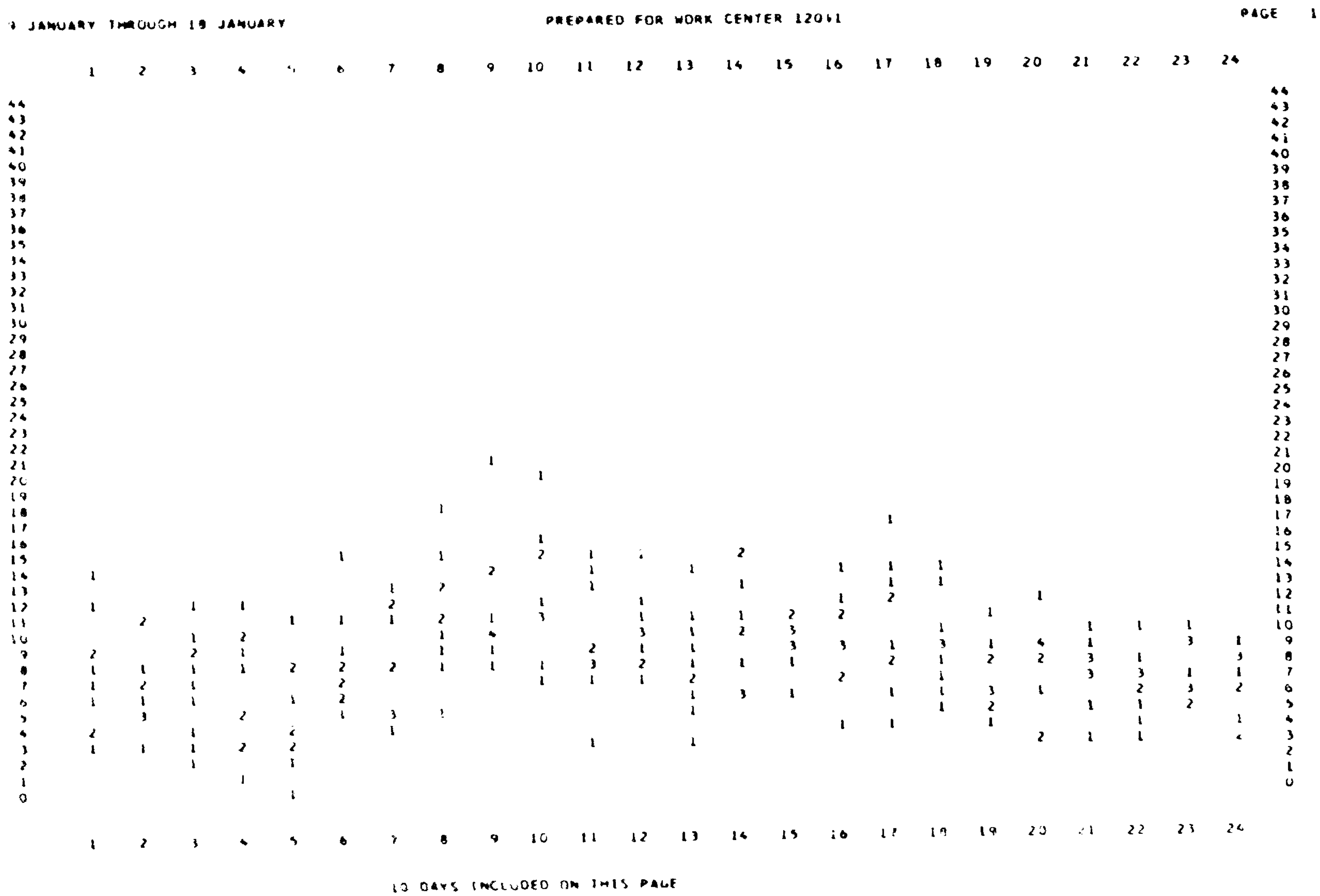


Fig. 28 -- Flight-line demands throughout the 24-hour day

(The ordinate gives the team size, the matrix gives the number of demands.)

flown might prove interesting. In short, the program can be used to display any clock-hour data and thus can inspect the ebb and flow across the 24 hours of the day. See also Sequential Frequency Distributions, Sec. IV.

The Manpower Utilization Sequence was initially developed to help the base manager make a better hourly distribution of his available manpower. The first set of real-world output made it apparent that the manpower sequence would be useful for addressing a much more profound problem--that of personnel assignment, which concerns how many of what skill should be assigned to the wing. The first time the sequence was used in this area, it uncovered a serious misalignment between available and utilized personnel. Some work centers were seriously undermanned and could meet demands only by prolonged overtime. Others were so grossly overmanned that there was concern over workforce morale because of the inactivity.

Remember that experience with the sequence is limited. As yet, there has been little chance to determine the relative importance of the various elements of the analysis and, hence, little chance to modify the sequence accordingly. The following items bear directly on further explorations with the sequence.

1. Utilization rates should be approached cautiously. They can be quite helpful in resolving the shift assignment problem--for example, matching the 24-hour distribution of manpower availability with the 24-hour distribution of potential demands (touchdowns).

   However, using them for the complex personnel assignment problem is another matter. How many men with what skills to assign to the various work centers is a function of the flying program. The nature of the relationship is not well understood. As far as utilization rates are concerned, it is certainly not linear. For certain, adjusting assignment to get 40-percent utilization in all shops is not a desirable solution.

2. Utilization rates may exceed 100 percent. This will occur when overtime is required. Persistent occurrence indicates improper shift assignment, inadequate manning or both.

3. Off-equipment work must be included in manpower assignment considerations. The bench load of some shops, such as radar, is often greater than the flight-line load. And bench load is not always low priority work; some bench fixes will be priority I, as discussed below.

Items 4 and 5 refer more to the specific methodology.

4. The operational definitions must be understood. The peak utilizations are not identical to demands. Utilizations reflect demands "smoothed out" by the scheduling process. Note, too, that the average demand rates on the final page give no hint of the variance. This shortcoming may be partially circumvented by referring to the daily detail listing procedure.

5. The program assumes that each work center has 3-shift manning. The average availability computations will be affected where this is not true. Note, too, that not all the availability data come from the dispatch board in job control. Special arrangements must be made to obtain the availability data for crew chiefs, munitions, tank farm, etc.

AGE UTILIZATION

This is a special purpose program designed to show flight-line AGE utilization (both active and standing). Initially, the plans were to display this data like the manpower utilization displays, i.e., showing touchdown patterns and availability juxtaposed with utilization. It quickly became apparent that AGE had unique characteristics that could be approached better by concentrating on AGE management.

Using program CET, select the cards containing an F in Col. 80 (format S). These are sorted as follows.

Major	Cols. 65-66	N	AGE
↓	Cols. 11-12	N	month
	Cols. 9-10	N	day
Minor	Cols. 13-16	N	hour-minute

This deck is placed behind the AGE display program, as shown in Fig. 29. No control card is necessary. Switches I/O, A, and B are set "on" for card input.

The AGE display in Fig. 30 shows that a given piece of equipment may be used several times during a fix. Hence the utilization durations would probably best be represented by taking the first time spotted or used as start time and the last time used or removed as the stop time. Until a program is available that combines the AGE

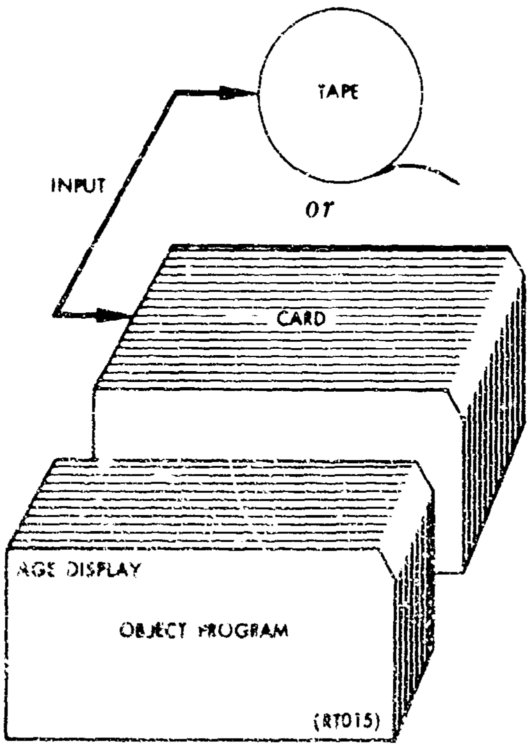


Fig. 29 -- AGE display program setup

used on a fix, the "by tail-number utilization" can be observed by a change in the sorting.

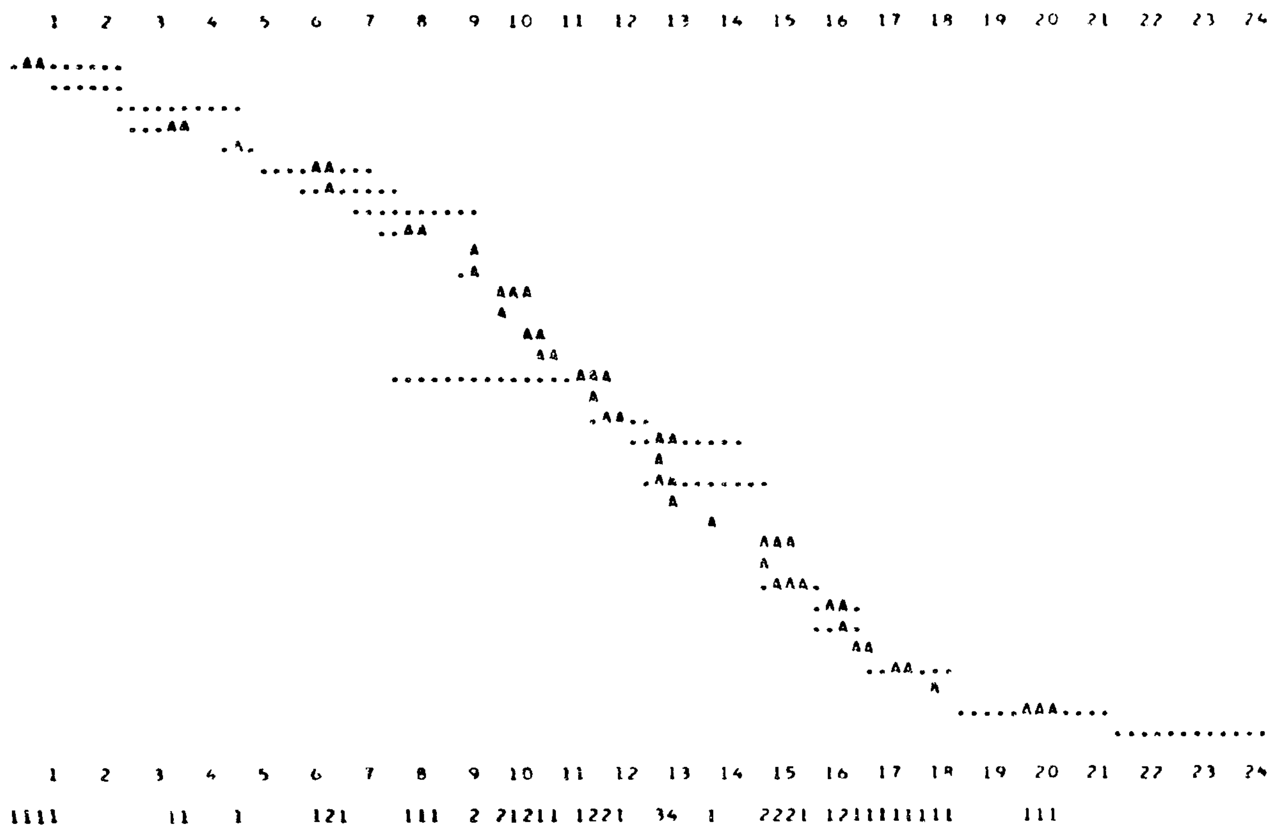
Major	Cols.	65-66	N	AGE code
	Cols.	11-12	N	month
	Cols.	9-10	N	day
	Cols.	35-38	N	aircraft tail-number
Minor	Cols.	13-16	N	hour-minute

AGE analysis is complicated because three kinds of AGE are used.

1. Dispatched AGE. "Owned" by the flight-line and used on the flight-line.
2. Nondispatch AGE. Carried from the work center and used on the flight-line.
3. Nondispatch AGE. Used only by the work center in the shop.

AGE analysis is also complicated because items range in cost from several dollars to several hundred dollars. Our attempts to deal with these factors were certainly far from satisfactory. They are offered only as a point of departure for designing a better system.

DATE 18-01 AGE EQUIPMENT TYPE 09 HYDRAULIC MULE MJ3



WC	ACFT IN	AGE IN
12042	0838	09
12042	7556	02
12052	0800	06
12052	7647	02
12052	7647	02
12042	0739	02
12052	0843	06
12042	0851	04
12052	7448	07
12052	7448	09
12041	0842	10
12042	7556	04
12041	0842	10
12052	7448	09
12041	0842	10
12052	0800	05
12041	0842	10
12041	[illegible]	10
12052	0843	06
12042	7556	04
12052	7448	0
[illegible]	7647	02
12042	7647	02
12042	0851	06
12042	7556	04
12042	7556	04
12043	0427	01
12042	7556	09
13340	0851	05
12043	0927	01
12042	0851	06
13340	7667	01
12043	7442	01

Fig. 30 -- AGE Utilization

("A" shows the AGE being used. An "A" is always printed in the 15-minute matrix cell even if used less than 7½ minutes. The dots preceding and following an "A" show the time the AGE was standing by the aircraft without being used. The using work center is shown under the column heading "WC". The summaries below show the counts of the 15-minute matrix cells in which an "A" appears, hence the actual number of AGE in use at any point in time might be less (but never more) than this entry. These data are analyzed by processing them through the manpower utilization sequence.)

Dollar value of AGE is determined from the base inventory list that BEMO (Base Equipment Management Office) provides. Based on an arbitrary decision, a list consisting only of items exceeding $1000 was selected. Two separate tables of AGE codes were constructed from this list, one for field maintenance (FMS) and one for armament and electronics (A&E).

Flight-line AGE utilization was recorded by a special team of data collectors, using RR form 304. Be assured that this was costly; it took 18 recorders to cover a wing of aircraft on a 24-hour operation. Although the data were excellent, the sampling had to be limited.

Bench AGE utilization was obtained by having the user enter the AGE code and number of users in Block L of the AFTO 200 forms immediately under the phrase "corrective action"; for example, 13/2 indicated that the team size yielded the elapsed time. Although there was no way to cross-check the bench utilization, the consensus of the Rapid Roger data collection group was that this method of collecting bench AGE was unsatisfactory because of erratic recording.

Two more statements are possible. First, once AGE utilization data are available, the list of items to monitor can be reduced. The basic question is how many of a given type are required. Items needed only once can be culled from the survey. Second, once the determination is made for frequently used items (need for more than one), undoubtedly some rewarding cost-effectiveness studies can be made in which cost is measured in dollar value of the AGE inventory and effectiveness is measured in speed of aircraft turnaround.

"ON-EQUIPMENT" BENCH REPAIR

At times, maintenance personnel remove an item from the aircraft, take it immediately to the bench, fix it, and replace it on the aircraft. As a result, the item does not go through conventional materiel control channels in a priority IV status. Rather, the bench repair becomes an integral part of priority I (on-equipment) action.

We discovered that we could include bench repair in the on-equipment data bank by making some minor additions to the recording procedures: enter the start and stop times on the AFTO 211 form (copy 1) along with the team size. These 211's are keypunched in form 300 format, using code "B" in the work order prefix, edited and included in the data bank. When discovered code "Z" identifies the bench repair data, and is used to avoid contaminating the K-97 deck, which includes the same information on copies 3 and 4.

The priority I bench repair actions are also correlated with the flight-line actions using the ETR (equipment temporarily removed) delay code. The sequence of actions is the following:

1. Remove the item using the action taken "P" on the 300 form.
2. Start the delay on the 300 form using the ETR code.
3. Fix the item at the bench. Record start time, stop time, team size, and actions taken on copy 1 of the 211.
4. Return to the aircraft and terminate the delay on the 300 form.
5. Install the item using action taken "Q" on the 300 form.

This entails a lot of recording. Were we to use it again, we would probably use one line of the ETR delay and one line of the 300 form, starting with the removal and ending with the installation for the fix action.

IV. 7044 PROGRAMS NOT YET AVAILABLE FOR 1401

There are several 7044 programs that would be desirable inclusions in the maintenance analysis package for base-level management. Unlike the methods described in Sec. III, these have all been used in a number of different settings, and most of the developmental problems have been resolved. However, they have not yet been converted to the 1401.

SPLATTERGRAMS

By displaying the write-ups sortie by sortie, the Splattergram program gives a snapshot history of each aircraft. It computes the write-up rates for each aircraft and prints them at the end of each tail-number. Tail-number data are then accumulated for the squadron and printed as squadron write-up rates on the last page of output. These data are saved and used to obtain repeat write-up evaluations as described below in the system repeat write-up analysis.

Because of interest in the Splattergrams, a number of variations have been developed, particularly for use with debriefing forms. The current display shown in Fig. 31 reads from top to bottom instead of from left to right, as did the original. The top to bottom sequence makes the program easier to adapt to a small computer, since the data may be processed and printed a record at a time.

Although this program can be used to process the special tape record output by Clint (containing the system break summaries by sortie), it will prove more useful for handling debriefing data, particularly when the data include the "system not used" distinction as does the 1-SAC-U82 data, for example. Note that the break-rates produced using the special Analysis of Variance program are erroneous when the data include systems not used on all sorties, and must be corrected by using the data provided by the intermittently used systems debriefing form. The Splattergrams provide automatically for this correction.

	AIRPLANE GENERAL									AUTOPILOT-WEAPONS						COMM/NAV						FIRE CNTL				INSTRUMENTS						
	1	2	3	4	5	6	7	8	9	10	13	14	15	18	19	20	23	24	25	26	28	29	30	32	33	34	37	38	39	40	41	42	
	AE	EG	EL	EN	FU	HY	MA	ME	PA	SH	AV	PI	ST	BO	GU	RX	DO	IF	IL	TA	AD	IN	UH	RA	SI	TB	AM	AV	HS	ST	EN	RA	A/C
305 10 11 NITE																												1					1
11 11 51-105			1																														1
12 11 51-105																			1					1									1
12 11 51-105																																	
13 11 51-105																																	
16 11 51-105	1																						1					1					1
21 11 SUIPPE														1																			1
21 11 51-105																								1									1
23 11 51-105																																	
2 12 NITE																								1									1
4 12 AAR																																	
5 12 51-105																																	
9 12 NITE	1																																1
16 12 51-105																								1								1	1
21 12 51-105																																	
21 12 51-105																								1									1
22 12 51-105																								1									1
23 12 51-105								1																1					1				1
26 12 51-105																								1							1		1
4 1 NIGHT																								1									1
24 1 51-105			1					1																1									1
26 1 AAR			1																				1	1									1
27 1 51-105																	1							1									1
28 1 51-105			1														1							1									1
29 1 SHUS																								1									1

	AIRPLANE GENERAL									AUTOPILOT-WEAPONS						COMM/NAV						FIRE CNTL				INSTRUMENTS						
	AE	EG	EL	EN	FU	HY	MA	ME	PA	SH	AV	PI	ST	BO	GU	RX	DO	IF	IL	TA	AD	IN	UH	RA	SI	TB	AM	AV	HS	ST	EN	RA	A/C
WRITE-UPS	2		4					2						1			2		1				2	14				2	1		1	1	19
SYS RPT			1														1							9									13
WU/SORTY	0.08		0.16					0.08						0.04			0.08		0.04				0.08	0.56				0.08	0.04		0.04	0.04	0.76

AIRCRAFT BREAK-RATE 19/ 25 = 0.76

Fig. 31 -- Splattergrams

(The tail number, day, month and sortie type are shown in the fields along the left margin. A "1" in the matrix indicates a write-up for the system indicated by the mnemonic codes along the top. The "SYS RPT" entries show the counts of write-ups followed by write-ups.

SYSTEM REPEAT WRITE-UP ANALYSIS

Two RAND studies suggest the usefulness of being able to determine, by statistical methods, whether repeat write-ups are occurring in nonrandom fashion.* These studies cluster write-ups by system (e.g., a write-up on landing gear system) rather than by the conventional part write-up; however, the technique employed requires sample sizes too great to be of practical use. To circumvent this, the following method was devised.

Given a sample of 50 sorties, assume that the radar system is written up 15 times. The proportion of write-ups (P= 15/50 = 0.30) can be used to predict the theoretical number of times that a write-up would follow a write-up if only random effects were operating--(0.30)(0.30) = 0.09. This reasoning can be extended to apply to all pairs of events. Assume a write-up is coded "1" and no write-up is coded "0"; then when we sweep down through the Splattergram, we would expect on the average that

"1" would follow "1" (0.30)(0.30)(50)=4.50 times
"1" would follow "0" (0.30)(0.70)(50)=10.50 times
"0" would follow "1" (0.70)(0.30)(50)=10.50 times
"0" would follow "0" (0.70)(0.70)(50)=24.50 times.

The numbers derived from the calculations can be used as theoretical frequencies (expected values) to be compared with actual data counts. This is done by the program. As each new record is read in, it is compared with the previous record to determine whether a "1" followed a "1", etc. The expected values are determined as described and a Chi-square test is made, as illustrated in Fig. 32.

To reduce meaningless output, the program suppresses the printing of systems analyses that have no repeat write-ups in the sample. The 7044 program combines the Splattergram and the Repeat Write-up Analysis, and also accounts for the "system not used" codes (such as used in the 1-SAC-U82 data). In this instance, the repeat write-up analysis

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*See W. H. McGlothlin and T. S. Donaldson, Trends in Aircraft Maintenance Requirements, The RAND Corporation, RM-4049-PR, June 1964, and A. F. Sweetland and T. S. Donaldson, Trends in F-101 Aircraft Maintenance Requirements, The RAND Corporation, RM-4930-PR, April 1966.

32-RADAR

	OBSERVED FREQ	THEORETICAL FREQ	D2/FT	P OBSVD	P THEOR
1-1	103	74.467	10.932	0.099	0.071**
1-0	178	204.225	3.368	0.171	0.196*
0-1	171	204.225	5.405	0.164	0.196**
0-0	591	560.082	1.707	0.567	0.537
		CHI-SQUARE =	21.412***		

Fig. 32 -- System repeat write-up analysis

(The "1-1" entry indicates a write-up followed by a write-up. The count of times this happens is shown under "OBSERVED FREQ". The theoretical frequencies are calculated as described in the text, and the theoretical proportions are obtained en route (e.g., "P THEOR" = (.30)(.30) = .09 and "THEORETICAL FREQ" (.09)(50) = 4.5) The observed proportions (P OBSVD) are obtained by dividing the observed frequencies by the number of pairs of sorties.)

can come as quite a shock: the Splattergrams suggest that the systems used only occasionally appear to be reasonably healthy. But the analysis program proves otherwise. This inevitably produces some hasty reviewing of the Splattergrams with some reorientation of perception on the "system not used" information.

WORK UNIT CODES ANALYSIS (5-DIGIT SUMMARIES)

The work unit code analysis summarizes on one page all the meaningful information on form 300 records. The need for the summary stems from several sources--most often from the desire to understand the role that hardware plays in write-up and recovery rate phenomena. The program builds a histogram of elapsed time distributions using team-size to delineate the histogram, as shown in Fig. 33. As with the other histograms, the percentage of jobs completed by a given hour is shown. The program determines the number and kinds of action taken, when discovered, and how malfunction codes encountered in the data sample. These counts are shown in order of descending frequency. Abbreviated verbal definitions of the how malfunction codes are included in the output. In addition to the usual computations--counts, totals, and means--the break-rate is also computed by reading in the sortie count or other appropriate base-line.

To avoid excessive and useless output, some rational basis is needed for selecting the work unit codes to process. Otherwise, the typical data sample of form 300 records will contain 600-1000 different work unit codes resulting in 600-1000 pages of output. As a first approximation of what to select, use program FREQ (see Sec. II) to obtain frequency counts of the work unit codes, and select only those codes that occur frequently enough to yield meaningful distributions.

This program assumes that the across-midnight records have been combined into one record or else eliminated. Data should first be tested for presence of stop times of 2400 and start times of 0001 which would indicate non-combined records.

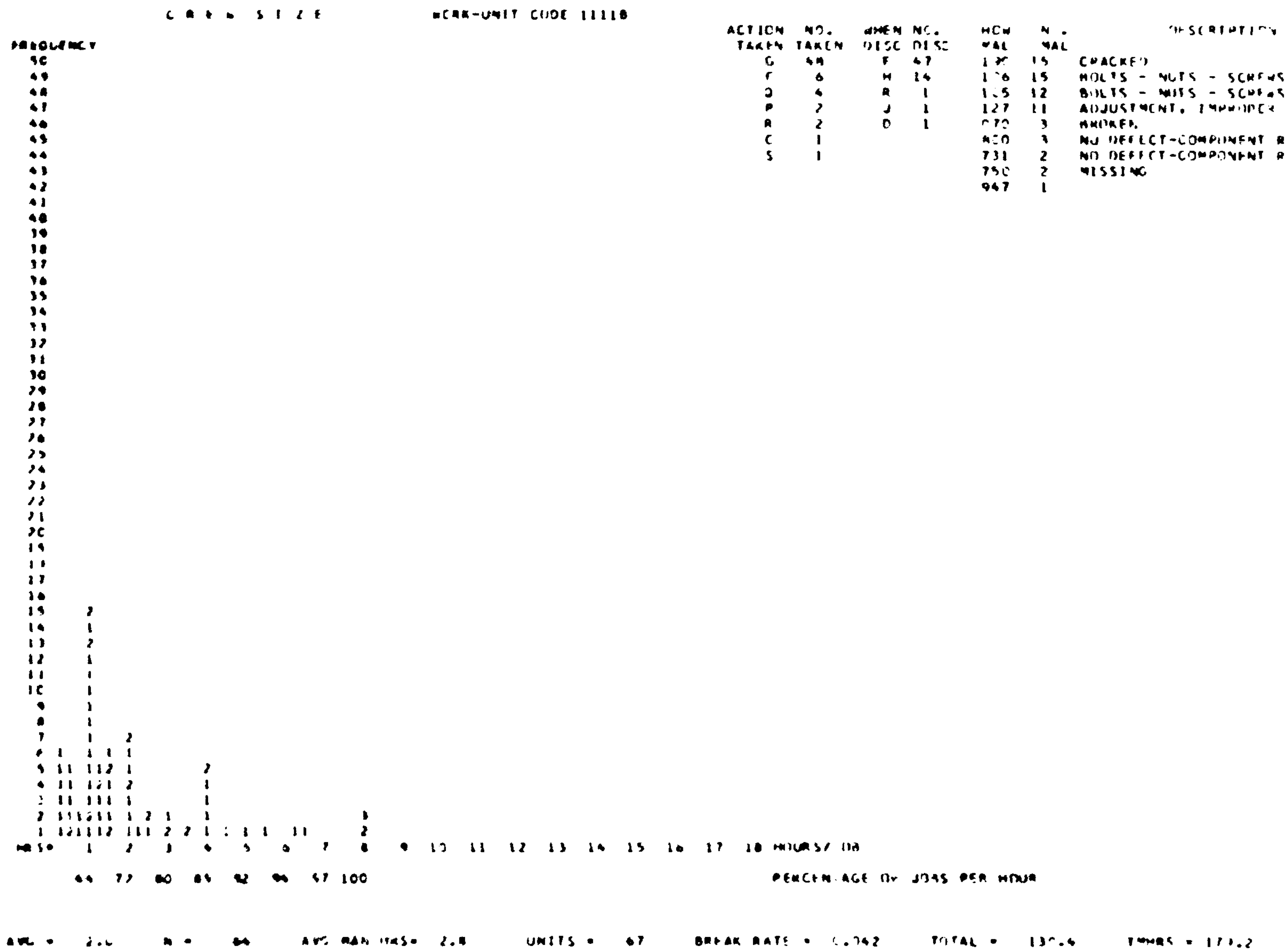


Fig. 33 -- Five-digit work unit code summary

(The entry "Avg" shows the average elapsed time. "Avg Man Hrs" is the average for each job. "Total" gives the total (net) fix time.)

SICK BIRD ANALYSIS

Maintenance management always want to know if they have any aberrant aircraft in their system. The sick bird program attempts to provide this information.

In general, aircraft problems show in the break-rate data before they show in the recovery data. The sick bird isolation determines whether individual tail-numbers show atypical write-up rates based on the number of sorties flown by obtaining the sortie and write-up counts for each aircraft and, using Chi-square, testing for non-homogeneity. Although hours flown has been used as a base-line for the Chi-square test, current investigation indicates that sorties flown is preferable, since hours flown can lead to erroneous conclusions.

Because most analyses are based on a month's flying, there are sampling problems when the data are separated by aircraft. If the 2-digit systems are used as a basis of calculation, the frequency counts are often too low to yield valid statistical determinations. And if the entire aircraft is used, desirable detail is lost. The sick bird approach attempts to overcome this by fractioning the data at a level between the aircraft and the 2-digit systems. Most often the write-ups are accumulated into six categories: aircraft basic, propulsion system, utilities, instrument-autopilot, communication-navigation, and weapons.

Based on the particular TMS, the instrument-autopilot, communications-navigations classifications are adjusted to give accumulations that are logically and statistically meaningful. For example, with simple aircraft they might all be combined in one group. The pre-processing program is adjusted to record the particular 2- or 3-digit system so that it may be processed appropriately. For example, the 2-digit systems

11000 Airframe
12000 Fuselage
13000 Landing gear
14000 Flight controls

are all coded "1" as basic aircraft. While this is going on, the

AUGUST BASIC AIRCRAFT WRITE-UPS/SORTIE													SAMPLE 1 -MAJOR-
BASE-LINE	FO	FT	D2/FT	MEANS	-3	-2	-1	0	1	2	3	4	5
8	52	12.33	127.70***	6.500							268		
7	8	10.79	.72	1.143				312					
8	27	12.33	17.47***	3.375					367				
7	15	10.79	1.65	2.143				413					
21	16	32.36	8.27**	.762			419						
14	3	21.57	15.99***	.214			426						
11	40	16.95	31.35***	3.636					428				
10	1	15.41	13.47***	.100			431						
8	3	12.33	7.06**	.375			434						
8	13	12.33	.04	1.625				436					
17	23	26.19	.39	1.353				438					
13	1	20.03	18.08***	.077			439						
17	10	26.19	10.01**	.588			440						
18	6	27.73	17.03***	.333			441						
11	49	16.95	60.61***	4.455					442				
15	21	23.11	.19	1.400				444					
11	39	16.95	28.69***	3.545					449				
17	13	26.19	6.65**	.765			451						
6	13	9.24	1.53	2.167				260					
6	6	9.24	1.14	1.000			287						
TOTAL 233	359												

WEIGHTED GRAND MEAN-- 1.541   1.778 -UNWEIGHTED-
CHI-SQUARE-- 368.02

DF-- 19

THE PROBABILITY IS BEYOND THE 0.001 LEVEL. THE DISTRIBUTION IS NOT HOMOGENEOUS.

Fig. 34 -- Sick bird output

(The base-line shows the number of sorties flown. FO and FT are the observed and theoretical frequencies. D2/FT is the difference between FO and FT squared and divided by FT squared and divided by FT. Means are FO divided by the base-line, i.e., average per sortie. The means are converted to Z-scores and plotted around their unweighted grand mean in the display at the right. Asterisks indicate statistical significance levels.)

program is also accumulating several summaries for each aircraft: sorties flown, hours flown, man-hours utilized, write-ups, and total down time. Then these summaries are input to the Chi-square program (see Fig. 34).

When the sick bird analysis indicates a problem, the next step in diagnosis is to check the Splattergrams to isolate the problem by system and by date. After that the daily displays are checked. If further information is desired, the 781's in aircraft records and/or the 992's in the various shops are scrutinized. The crew chief, of course, will have much anecdotal material.

SEQUENTIAL FREQUENCY DISTRIBUTIONS

The Sequential Frequency Distribution program summarizes and displays events across 24-hour periods. Its inputs have the same format as those for the Manpower Utilization Summary, which are the frequency counts for each hour of the day. The program creates a frequency distribution for each hour and displays it vertically to reveal the ebb and flow of daily events, as shown in Fig. 35. The display also indicates the frequency and magnitude of unusual occurrences, thus alerting management to the extremes that it can expect. This is generally the first step in formulating procedures for dealing with a dilemma. The display is used extensively in manpower and AGE utilization analyses.

Most processing needed to generate this display is contained in the Manpower Utilization Sequence. This is a collection of summary records of zero time duration events such as touchdowns, schedule deviations, and other data that do not have both start- and stop-time entries. The Hourly Frequency Accumulate program also produces summary records for data having both start- and stop-time entries: manpower utilized, AGE utilized, sorties flown, lags, delays, fix times, aircraft status, and so on. The Sequential Frequency Distribution program may display both types of data. For more detailed work-center analysis, a special version of this program is used. Time zero is set to touchdown time instead of midnight, thus orienting the summary to sorties rather than to shifts.

WORK CENTER 331 DATE 10

NO.-MEN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
19																								
18																								
17																								
16																								
15																								
14														1										
13																	1							
12															2									
11									1									1						
10															2	3	1							
9										1			1						1		1			
8								1				1		3	1	1	2	4	2	1				
7											1	2	3		1	3	2	1						
6		2						2	1	2	3		1	2	4	3	3	4	3	4	4	3		
5								1		1	1	1	3	2	2	2	1	3	2	1	1			
4	2	1	1					4	5	2	2	4	4	3	3	4	6	2	5	4	4	3	5	1
3	1	1	2	1		1	4	2	2	1		2	1	2			2	1		2	2	1	1	1
2	2	1	3	6	4	3	4	7	12	8	6	8	7	6	5	6	5	3	6	7	6	9	7	7
1	1	1				1		1	1	2	3	3	1			1	1			1		1	1	
0	23	23	23	22	25	24	21	11	7	12	13	8	8	10	9	6	5	10	10	9	11	12	15	20
MEAN	0.6	0.8	0.6	0.5	0.3	0.3	0.7	2.1	2.3	1.9	1.8	2.3	2.9	3.1	4.0	4.0	4.0	3.7	2.9	2.6	2.5	1.8	1.3	0.7
SIGMA	1.2	1.7	1.1	0.9	0.7	0.8	1.1	2.2	2.2	2.3	2.2	2.2	2.6	3.3	3.7	3.2	3.2	3.3	2.8	2.3	2.5	1.9	1.5	1.1

Fig. 35 -- Flight-line demands throughout the 24-hour day

(The ordinate give the team size, the matrix gives the number of demands.)

MULTIVARIATE METHODS

From time to time we have used several of the BIMD programs written by the Department of Preventive Medicine and Public Health, School of Medicine, UCLA. Two have proven quite useful--Multiple Regression and Factor Analysis. Currently, we are testing several multiple regression programs available for the 1401. Should one prove suitable, it will be included in the program package. Thus far, we have been unable to locate a Factor Analysis program adaptable for the 1401.

V. FURTHER PROGRAMMING NEEDS

Extensive analysis with the RAND/TAC system has revealed that the greatest weakness of the maintenance package is in the area between the software the manufacturer provides (e.g., merging and sorting routines) and the programs. The missing elements are extensions of routines normally described as PCAM actions--those concerned with selecting subsets of data, tagging data, relocating data fields, and so on. The needs also include a simplified report generator, since most report generators require too much training to be used by those with no programming experience. These needs are described in the following sections.

REPORT GENERATOR

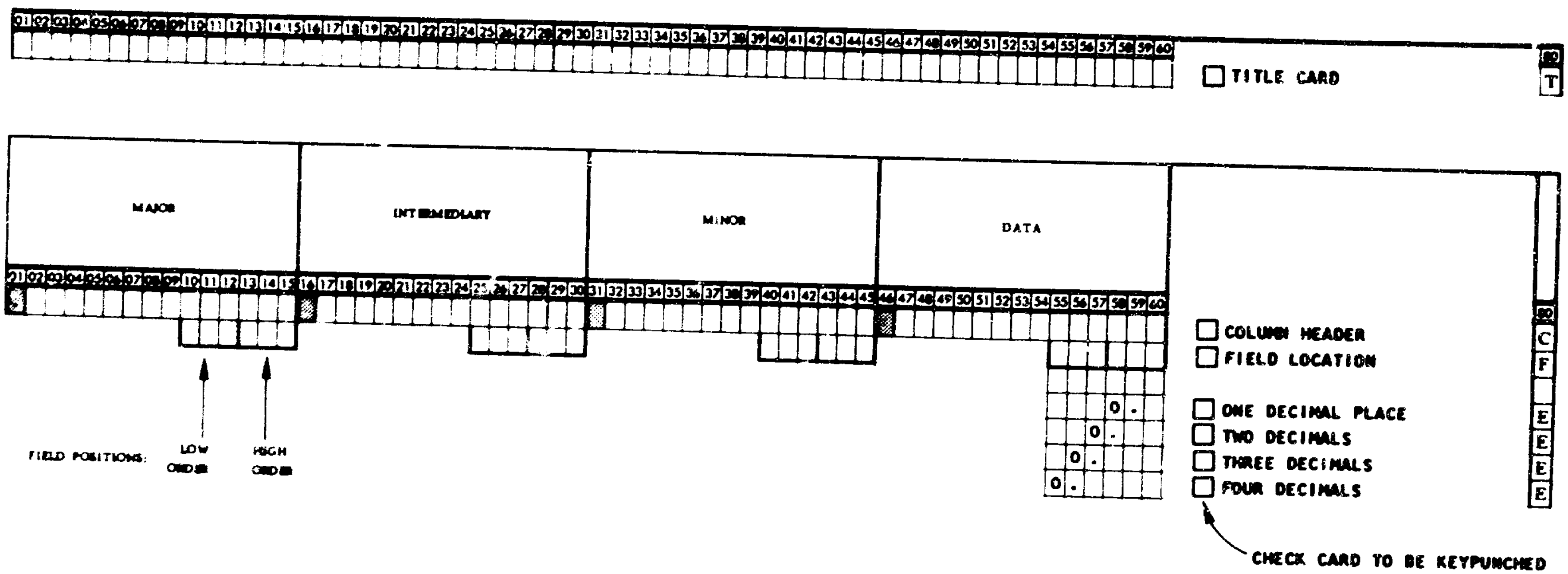
The program described now supplies a report generator so simple that most people can learn to use it in less than 15 minutes if they understand simple sorting concepts--majors, intermediates, and minors. Most of the material is in control card form, and is easy to learn because the output is restricted to fixed field locations.

Major	Cols. 1-15
Intermediate	Cols. 16-30
Minor	Cols. 31-45
Data	Cols. 46-60

The analyst provides four or fewer control cards, using the Report Generator Instruction Sheet as indicated in Fig. 36.

1. A general title card, which may be omitted.
2. A field identification (field header) card, which may be omitted.
3. A field location card, which is mandatory. This locates the low- and high-order positions of the major, intermediate and minor control fields and the data. It is not necessary to use all three control fields; any combination can be used. The output will appear in the location defined. For example, if a field location is given only for the intermediate, i.e., punched in Cols. 25-30 of the field location card, with blanks in Cols. 10-15 (major location) and Cols. 40-55 (minor location), only the intermediate field will be sensed and printed and it will appear, right-justified, in Cols. 16-30 of the output.

REPORT GENERATOR INSTRUCTION SHEET



NOTE: TITLE AND COLUMN HEADER CARDS MAY BE OMITTED.

IF THE DECIMAL EDIT CARD IS OMITTED, NO DECIMAL WILL BE PRINTED.

THE LOW AND HIGH ORDER FIELD POSITION MUST BE RIGHT-ADJUSTED AND PRECEDED BY ZEROS.

Fig. 36 -- Report Generator Instruction Sheet

4. An edit mask card. This locates the decimal place which is edited into the data field just before printing. If this card is omitted, no editing transpires (the program assumes the data are in whole numbers).

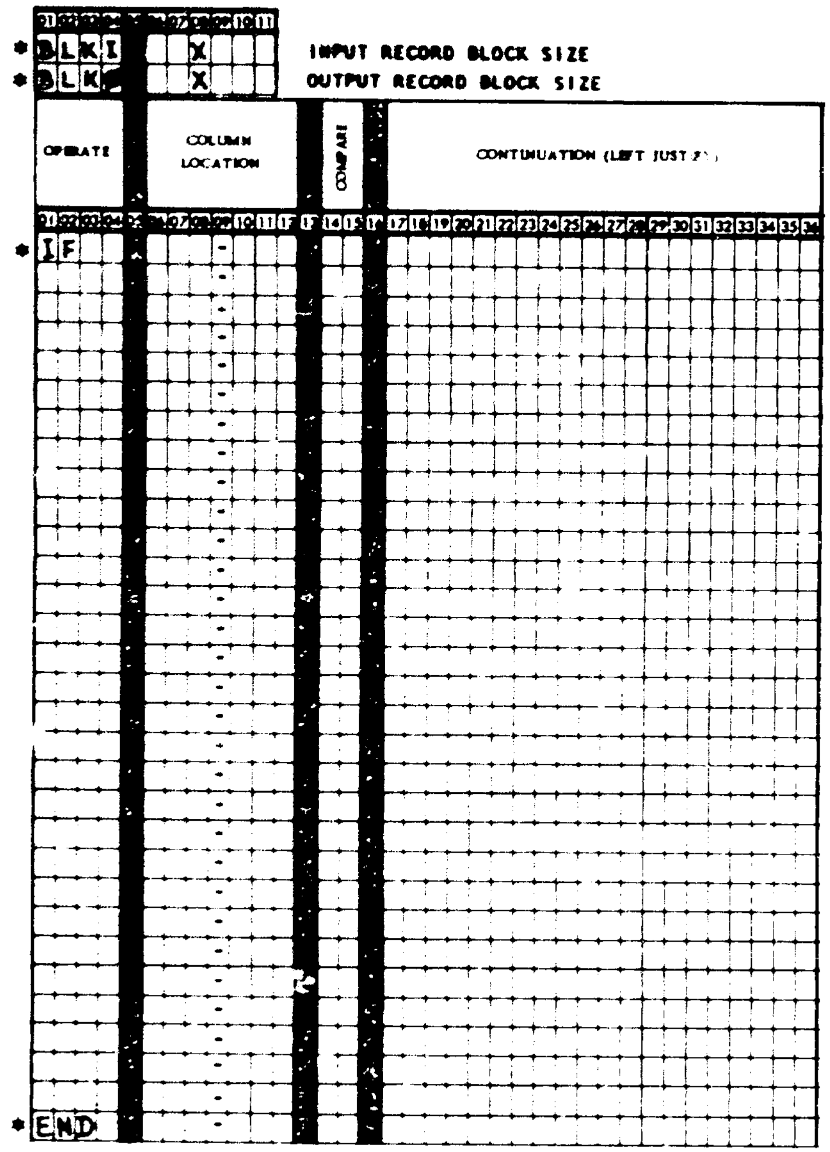
The desire to include this program in the package is entirely defensive. The biggest constraint in any computer venture is programmer time, and the biggest time consumers are individuals who are naïve in data processing. So we are attempting to relieve the programmer of unnecessary work (the bulk of programming requests are for special listings) and to begin simultaneously to overcome some data processing naïveté. Obviously, the individual who tries out various data combinations before he contacts the programmer has a better chance of getting a working program than the person who uses the programmer as a loop in a sequence of trials and errors.

As visualized, the Report Generator program reproduces the field location information on page 1 of the output to facilitate cross-checking. Output includes record counts, totals and means. In addition, the summary data include both nonzero and total record counts, as well as their corresponding means.

DATA SELECTING, TAGGING, AND REFORMATTING

Most projects and exercises reveal the need to handle data in a new and different manner. Frequently, new files of information must be added to the data bank or subsets of old files must be extracted and processed in a different way. An example would be the need to add the Forward Air Controllers report (or the Range Report Data) to the data bank to determine whether any interrelationships occur.

The program we have in mind, shown in Fig. 37, accepts a set of control cards such as shown below. Translated, the input block size and record length is 1 and 80. The output record length is 1320 characters long (a block of 10 records of 132 characters each).



LEGAL CODES COLUMNS 1-4

BLKI
BLKØ
IF
AND
MØVE
PLUG
ØUTP
END

Left justify

LEGAL CODES COLUMNS 14-15

EQ = Equal
GT = Greater Than
LT = Less Than
EG = Equal or Greater Than
EL = Equal or Less Than

(Leave Cols. 14-15 blank for PLUG or MØVE commands.

If blanks are to be Plugged, leave Cols. 17-34 blank.

Columns 5, 13, and 16 must always be blank.

Column Locations must be preceded with zeros.

MØVE must have "X" (11 punch) in Col. 20.

*Records must be in Control Deck.

Fig. 37

```
BLKIN 01X080
BLKOU 10X132
IF    080-080 EQ 0
AND   011-012 GT 06
AND   011-012 LT 20
PLUG  081-084     ABCD
MOVE  035-038     085-088
OUTP
IF    080-080 EQ 2
MOVE  002-005     085-088
OUTP
END
```

Two "if-output" sets of conditions (if-and) and commands (plug, move and outputs) are used. The first tells the computer that if Col. 80 contains a zero and the contents of Cols. 11-12 are greater than 06 and less than 20, plug (tag) "ABCD" into Cols. 81-84 and move the contents of Cols. 35-38 to Cols. 85-88. On sensing "OUTP", the computer outputs the new record. If the conditions of the first "if-and" set are not met, the computer moves to the next "if-output" set and tests: If Col. 80 contains a "2", Cols. 2-5 are moved to Cols. 85-88 and this record is output. If no conditions are met before sensing the "END" card, a new record is read and the sequence iterated. The output tape can now be sorted on Cols. 85-88 and processed in the usual manner.

The program thus allows the user to select any subset or subsets of data from a data bank consisting of mixed formats, tag each of these in any manner desired, and move any data fields into a common format for sorting and processing.

SELECT DATA BY MATCHING FILES

Occasionally, there may be two files (tapes) of records, one containing the desired characteristics and the other containing matched sets of data (desired) as well as a number of undesirable records. This would occur when we wished to select maintenance records that match a discrete set of operations records. Before using, both tapes are sorted on the appropriate fields. The control cards would look like those shown below.

```
BLKIN 01X084
BLKOU 01X084
IF    018-019 EQ 023-024
AND   050-052 EQ 050-052
OUTP
END
```

Translated, the inputs are single records 84 characters long; the outputs are identical. The conditions and commands are translated as follows. If the contents of Cols. 18-19 on tape unit 1 equal the contents of Cols. 23-24 on unit 2, and also Cols. 50-52 of unit 1 equal Cols. 50-52 of unit 2, the record on unit 2 is written on tape unit 3. The ultimate program should be able to handle match-selections of greater complexity than that indicated by the example.

General Purpose List

When beginning an analysis, the analyst spends much time poring over the queue sorts (which show the data pictorially) and a straight listing of the data, record by record.* More often than not, he wished to check blocks of data in the listing. A block is defined here as all the data containing a common element--a specific sortie, tail number, mission type, etc. These data blocks are amazingly difficult to locate in the mass of output given on an 80-80 listing. We would like to be able to offer the computer the following.

```
BLKIN  10x84
BLKOU   1x84
SKIP   035-038 1
SKIP   001-001 3
END
```

The translation of input and output block size and record length is as before. If a change is sensed in the contents of Cols. 35-38, one space is skipped on the printout. Similarly, a change in Col. 1 would cause three spaces to be skipped. The data, of course, must be sorted first on the fields to be tested. As a general statement,

*This is generally referred to as an 80-80 listing, although record lengths often exceed 80 characters.

changes in the major field are associated with the SKIP 3 instruction, intermediates with SKIP 2, and minors with SKIP 1.

The Spread-Field List

The spread-field list provides a listing of each field isolated from the adjacent one by blanks, thus easing the eyestrain of the error editor. Thus the spread-field listing of the 300 form records would appear as shown:

TAIL	SU	DAMO	B/W/C	RPTNO	
7444	FJ	1016	21231	14515A	
7444	FJ	1016	22312	14515B	etc.
7444	FJ	1016	24311	14515C	
etc.					

Spreading the 80-80 listing so that it corresponds to the field separation of the record forms materially facilitates the cross-checking process. The spread-listings should be double-spaced so the editor can enter his corrections (preferably in red) under each aberrant entry. Each recording form requires a program. The field heads should be identical or very similar to the entries on the recording forms, and should appear at the top of each page. (Note that with the addition of the capability of printing title cards, the Select, Tag and Reformat program could produce this.)

INTERSPERSED GANG-PUNCH EQUIVALENT

There is one desirable addition to the package of software--the computer equivalent of an interspersed gang-punch. This is needed when two different sets of data exist and entries from one set must be transcribed onto the records of another. Thus we might have a multiple format record consisting of Op-Rep 4 records and sortie description data and we wish to copy the target characteristic from the Op-Rep 4 into a blank field on the sortie data. Assume we have used the Select, Tag and Reformat program and have built a set of records as shown below.

Op-Rep 4 24542 (located in Cols. 131-135)
Sortie (blank)
Sortie "
" "
Op-Rep 4 24543
Op-Rep 4 24544
Sortie (blank)

The following control cards would be used:

BLKIN 10x138
BLKOU 10x138
GANG 131x135
END

The computer reads in records until it finds a non-blank entry in Cols. 131-135. It stores this entry and "gang-punches" it into Cols. 131-135 of all subsequent records containing a blank in Cols. 131-135. On sensing a non-blank, it stores this new entry and continues. We are not so optimistic as to feel that the final version of this program would be so devoid of checks. Thus far, we have always had to write a special program for the particular set of data involved since the combination of records collected from disparate sources has been neither simple, direct nor painless. Ultimately, we feel that the previous programs will be combined into one general purpose program (possibly excepting the function of selecting matching files). Whether or not we combine the programs depends on the saving in throughput time, which is determined by the trade-off between input-output time (including tape rewind) and internal computing time.

Appendix A

KEYPUNCH FORMATS AND LIST OF FORMS AVAILABLE FOR RAND/TAC SYSTEM

For the reader's convenience, this appendix lists the forms included in Appendixes B through G of Volume I for the RAND/TAC system. Also included in this appendix are the Keypunch Formats.

Operations Forms

CD form 101	Sortie Debriefing
CD form 101	Debriefing of Combat
CD form 101	Degradation Factors During Flight to and from Target
CD form 101	Degradation Factors During Combat
CD form 101	Combat Crewmembers' Comments and Recommendations
CD form 101	BDA
CD form 102	Joint Services Anti-Aircraft Fire Incident and Damage Report
CD form 103	FAC Poststrike Debriefing Checklist

Maintenance Forms

MIP form 305 test	
RR form 300 test	Maintenance Data Collection Record
RAND form 300	Maintenance Data Collection Record
RAND form 302	Sorties Flown, Scheduled or Scrambled
RAND form 303	Aircraft Status Summary
RAND form 305	Manpower Availability
RAND form 306	AGE Utilization
RAND form 307	Mission Go
RAND form 308	Deviations-Degradations
RAND form 309	General Purpose Information Record
RAND form 300	F-4C

Supply Forms

CD form 303	Record of Cannibalization
CD form 401 (Part A)	Demand Register
CD form 401 (Part B)	Demand Register
CD form 402	Receipt or Cancellation Register
CD form 403	NORS register

Personnel Forms

CD form 200	Personnel Data Worksheet
CD form 201	Personnel Information Data
CD form 202	Supervisor's Information Data
CD form 204	Aircrew Experience Record

Facilities Forms

Form F-1	Airfield Facilities Survey--Monthly
Form F-2	Airfield Operations, Safety and Weather Survey--Daily
Form F-3	Motor Pool Survey--Weekly
Form F-4	Electrical Power Generation Survey--Monthly
Form F-5	POL Facilities Survey--Monthly
Form F-6	Munitions Facilities Survey--Monthly
Form F-7	Supply Facilities Survey--Monthly
Form F-8	Maintenance Facilities Survey--Weekly

Keypunch Formats

Edit Program Input	
Format A	Debrief Summary
Format B	Form 300 (On-aircraft maintenance)
Format C	Sortie-Scheduled and/or Flown
Format D	Status Card
Format E	Manpower Available
Format F	AGE Utilization
Format G	Mission Go
Format H	Deviation/Degradation
Format I	General Purpose Comment
Edit Program Output	
Format J	Debrief Summary
Format K	On-Aircraft Maintenance
Format L	On-Aircraft Work Delay
Format M	Sortie Flown
Format N	Sortie Scheduled, Not Flown
Format P	Sortie Comment
Format Q	Aircraft Status
Format R	Manpower Available
Format S	AGE Utilization
Format T	Mission Go
Format U	Deviation/Degradation Comment
Format V	General Purpose Comment
Program Output Summary Cards	
Format W	24-hour Spread
Format X	Analysis of Variance
Format Y	RECSUM
Format Z	Frequency Count
Format AA	Off-Equipment (AFTO 211) Manhour
Program Control Cards	
Format C1	Lag/Delay
Format C2	Analysis of Variance
Format C3	Aircraft Histogram
Format C4	Table Loading Stopper
Format C5	Manpower Utilization Title Card

Keypunch Instructions and Formats (Continued)

Program Control Cards (Continued)

Format C6	Edit Program Gangpunch Master Card
Format C7	Display Program Date Select
Format C8	Display Program Tape Output
Format C9	Tape Input
Format C10	General Title Card
Format C11	Histogram Title Card
Format C12	Field Selector
Format C13	Compute Elapsed Time Program--Code Selector
Format C14	Frequency Count (FREQ) Field Locator Card
Format C15	Chi-Square Title Card
Format C16	Chi-Square Field
Format C17	Correlation Field Designation
Format C18	Correlation General Title Card
Format C19	Correlation Field Designation Table Stopper Card
Format C20	Correlation Independent Variable Test Control Card
Format C21	Analysis of Variance Header Card

Master Tables

Format M1	Work Center Master
Format M2	Tail Number Master
Format M3	2-Digit System Table
Format M4	Edit Program AGE Table

Clint Program Summary Records

Format R1	Aircraft
Format R2	2-Digit System
Format R3	Work Center

Combat Dragon Card Form 101 Operations Cards

Format CD1	Sortie Debriefing
Format CD2	Debriefing of Combat
Format CD3	En Route Degradation Factors
Format CD4	Degradation Factors on Target
Format CD5	Flight Crew Comments and Recommendations
Format CD6	BDA
Format CD7	Battle Damage Assessment Remarks

Combat Dragon Supply Edit Output Cards

Format CD8	Demands, Receipts and Cancellations
Format CD9	Cannibalization Tape Format
Format CD10	NORS

Combat Dragon Supply Edit Input Cards

Format CD11	Demands, Receipts and Cancellations
Format CD12	Cannibalization Card Format
Format CD13	NORS

EDIT PROGRAM INPUT

DEBRIEF SUMMARY

FORMAT A

DATE		AIRCRAFT TAIL NUMBER	MISSION NUMBER	CHOCK TIME		SYSTEM FUNCTIONING: BLANK = USED AND OK; 1 = USED – MALFUNCTION; 2 = NOT USED	COMMENTS OR ADDITIONAL CODES	CARD CODE
DAY	MO.			HR.	MIN.			
								D

FORM 300 (ON-AIRCRAFT MAINTENANCE)

FORMAT B

AIRCRAFT TAIL NUMBER	SUFFIX	DATE		BASIC WORK CENTER	REPORT		WORK ORDER PREFIX	START TIME		STOP TIME		CREW SIZE	WORK UNIT CODE	ACTION TAKEN	WHEN DISCOVERED	HOW MALFUNCTION	UNITS PRODUCED	ASSISTING WORK CENTER	AFTO 211 ACTION	AIRFRAME HOURS	SYMBOL	MISSION DAY	MISSION NUMBER	LOCAL USE		CARD CODE
		DAY	MO.		NUMBER	LINE		HR.	MIN.	HR.	MIN.															
																										0

SORTIE — SCHEDULED AND/OR FLOWN

FORMAT C

DATE		MISSION NUMBER	LOAD CONFIGURATION	SCHED. TAKEOFF		SCHED. DURATION		AIRCRAFT TAIL NUMBER	ACTUAL TAKEOFF TIME		CHOCK TIME		COMMENTS	CARD CODE
DAY	MO.			HR.	MIN.	HR.	MIN.		HR.	MIN.	HR.	MIN.		
														2

EDIT PROGRAM INPUT

STATUS CARD

FORMAT D

	AIRCRAFT TAIL NUMBER		STATUS CODE		INTO STATUS		OUT OF STATUS		NORS WORK UNIT CODE	NORS G N CODE	JULIAN DATE		CARD CODE
					HRS.	TENTHS	HRS.	TENTHS			YEAR	DAY	
													3

MANPOWER AVAILABLE

FORMAT E

[illegible]			WORK CENTER	AVAILABLE			FIRST SHIFT				SECOND SHIFT				THIRD SHIFT					CARD CODE
				FIRST SHIFT	SECOND SHIFT	THIRD SHIFT	START		STOP		START		STOP		START		STOP			
AT	MF			SKILL LEVEL	SKILL LEVEL	SKILL LEVEL	HR.	MIN.	HR.	MIN.	HR.	MIN.	HR.	MIN.	HR.	MIN.	HR.	MIN.		
																				5

AGE UTILIZATION

FORMAT F

[illegible]		EQUIPMENT		AIRCRAFT TAIL NUMBER	USING WORK CENTER	SPOT TIME		START TIME		STOP TIME		REMOVE TIME			CARD CODE
[illegible]	MF	TYPE	NUMBER			HR.	MIN.	HR.	MIN.	HR.	MIN.	HR.	MIN.		
															6

EDIT PROGRAM INPUT

MISSION GO

FORMAT G

DATE		AIRCRAFT TAIL NUMBER	TIME			CARD CODE
DAY	MO.		HR.	MIN.		
						7

DEVIATION/DEGRADATION

FORMAT H

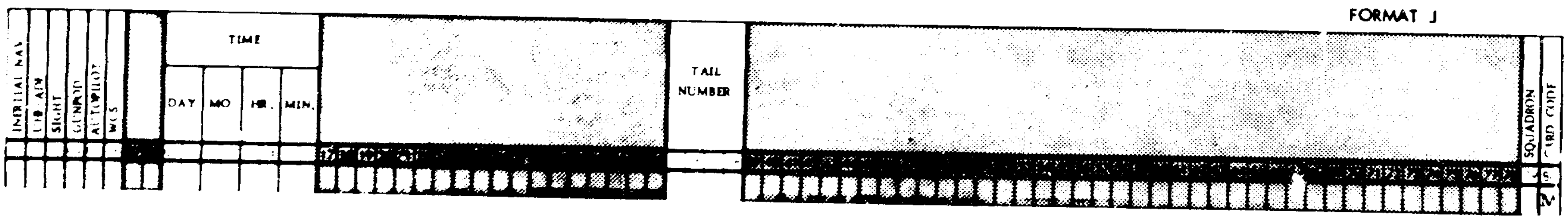
DATE		AIRCRAFT TAIL NUMBER	MISSION NUMBER	SCHED. TAKEOFF		DEVIA-TION CODE	WORK UNIT CODE	COMMENTS OR ADDITIONAL CODES	CARD CODE
DAY	MO.			HR.	MIN.				
									8

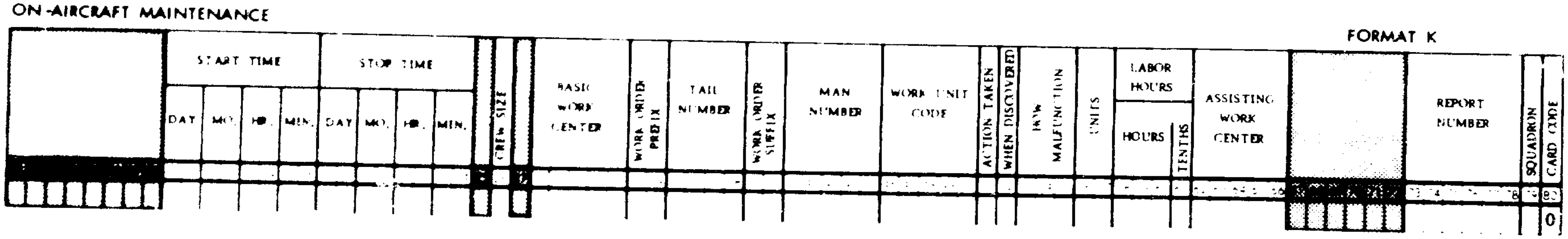
GENERAL PURPOSE COMMENT

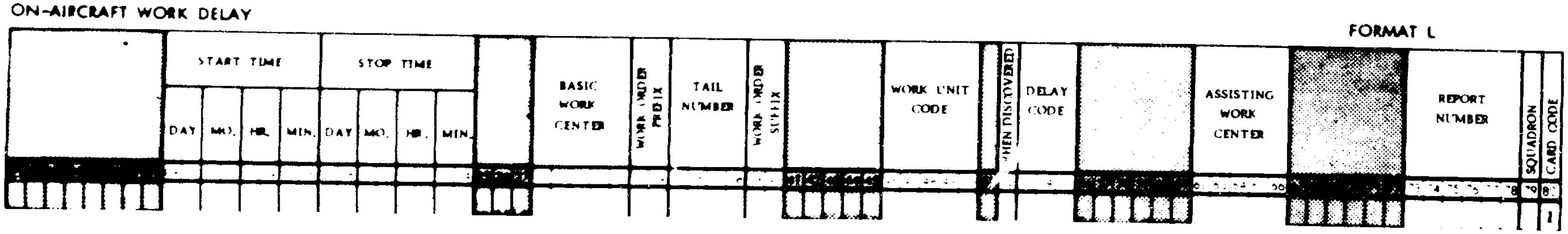
FORMAT I

DATE		AIRCRAFT TAIL NUMBER	MISSION NUMBER	TIME		COMMENTS	CARD CODE
DAY	MO.			HR.	MIN.		
							9

EDIT PROGRAM OUTPUT







EDIT PROGRAM OUTPUT

SORTIE FLOWN — **FORMAT M**

SCHEDULED TAKEOFF				ACTUAL TAKEOFF				LANDING					SCHED. FLY TIME			TAIL NUMBER		DEVIATION CODE	CREW			LOAD CONFIGURATION	MISSION		SQUADRON	CARD CODE
DAY	MO.	HR.	MIN.	DAY	MO.	HR.	MIN.	DAY	MO.	HR.	MIN.		HR.	MIN.					1	2						
																										2

SORTIE SCHEDULED, NOT FLOWN — **FORMAT N**

SCHEDULED TAKEOFF				SCHEDULED TAKEOFF					SCHED. FLY TIME			TAIL NUMBER		DEVIATION CODE	CREW			LOAD CONFIGURATION	MISSION		SQUADRON	CARD CODE
DAY	MO.	HR.	MIN.	DAY	MO.	HR.	MIN.		HR.	MIN.					1	2						
																						S

SORTIE COMMENT — **FORMAT P**

MISSION CODE		Load Configuration	TIME				Last 2 digits of Load Configuration		CREW 1		CREW 2	COMMENTS (1)	TAIL NUMBER	COMMENTS (cont.)		COMMENTS (cont.)	SQUADRON	CARD CODE
			DAY	MO.	HR.	MIN.												
																		B

EDIT PROGRAM OUTPUT

AIRCRAFT STATUS — FORMAT Q

	INTO STATUS				OUT OF STATUS					STATUS CODE		TAIL NUMBER		NORS WORK UNIT CODE	N or G		SQUADRON	CARD CODE
	DAY	MO.	HR.	MIN.	DAY	MO.	HR.	MIN.									79	80
																		3

MANPOWER AVAILABLE — FORMAT R

WORK CENTER	DATE			MANPOWER AVAILABLE BY HOUR																									CARD CODE
	DAY	MO.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		80
																													E

AGE UTILIZATION — FORMAT S

SPOT TIME				START TIME				STOP TIME					QUANTITY	AGE TAIL NUMBER	REMOVE TIME			TAIL NUMBER	SUFFIX	NOUN	WORK CENTER	NOUN (cont.)		AGE CODE		NOUN (cont.)		SQUADRON	CARD CODE
DAY	MO.	HR.	MIN.	DAY	MO.	HR.	MIN.	DAY	MO.	HR.	MIN.				HR.	MIN.													
															29 30	31 32		35 36 37 38	39 40	41 42 43 44 45	46 47 48 49 50	51 52 53 54 55 56 57 58 59 60 61		65 66		73 74 75 76		79	80
																													F

EDIT PROGRAM OUTPUT

MISSION GO

FORMAT T

	MISSION GO TIME					TAIL NUMBER		SQUADRON	CARD CODE
	DAY	MO.	HR.	MIN.					
									G

DEVIATION/DEGRADATION COMMENT

FORMAT U

MISSION CODE	First 2 digits of Deviation code	TIME				Dev. code last digit	COMMENTS (1)	TAIL NUMBER	COMMENTS (cont.)	WORK UNIT CODE	COMMENTS (cont.)	SQUADRON	CARD CODE
		DAY	MO.	HR.	MIN.								
													H

GENERAL PURPOSE COMMENT

FORMAT V

COMMENTS (1)	TIME				COMMENTS (cont.)	TAIL NUMBER	COMMENTS (cont.)	WORK UNIT CODE	COMMENTS (cont.)	SQUADRON	CARD CODE
	DAY	MO.	HR.	MIN.							
											9

PROGRAM OUTPUT SUMMARY CARDS

24-HOUR SPREAD SUMMARY CARD

FORMAT W

WORK CENTER OR A/E CODE	DATE			24-HOUR SPREAD																								MANHOURS			PRI/SEC	CARD CODE
	DAY	MO		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	HOURS	TENTHS			

ANALYSIS OF VARIANCE OUTPUT SUMMARY

FORMAT X

SORTIE COUNT		FRE-QUENCY COUNT	MINOR CONTROL CODE		MAJOR CONTROL CODE	

RECSUM PROGRAM SUMMARY

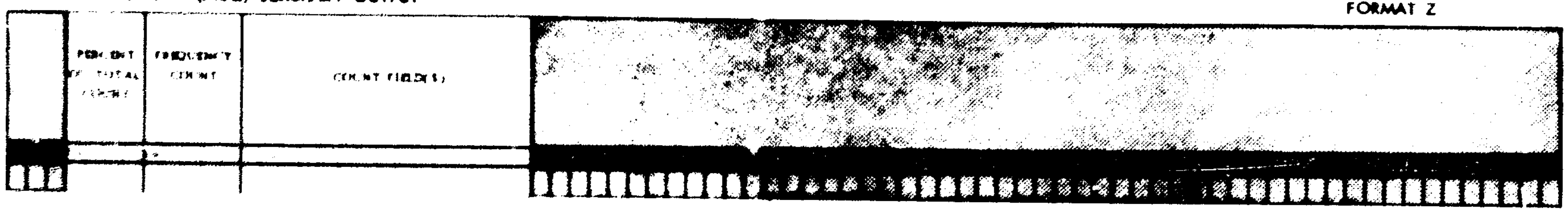
FORMAT Y

MAJOR CODE	MINOR CODE	COUNT (ALL RECORD)	COUNT (ZERO DATA OMITTED)	LAG	DELAY	NET FIX	GROSS FIX	MANHOURS	NORS	NORM	FLYING HOURS	UNITS		BREAKS	WRITE-UPS

PROGRAM OUTPUT SUMMARY CARDS

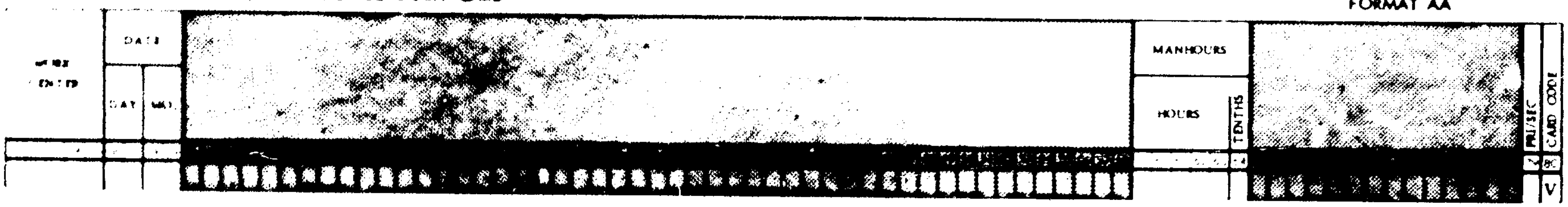
FREQUENCY COUNT (FREQ) SUMMARY OUTPUT

FORMAT Z



OFF-EQUIPMENT (AFTO 211) MANHOUR SUMMARY CARD

FORMAT AA



MASTER TABLES

WORK CENTER MASTER

FORMAT M1

WORK CENTER NAME

CARD CODE

* 12 PUNCH

TAIL NUMBER MASTER

FORMAT M2

AIRCRAFT SERIAL NUMBER

TAIL NUMBER

ORGANIZATION

CARD CODE

* 11 PUNCH

2-DIGIT SYSTEM TABLE

FORMAT M3

NOUN

CARD CODE

* PUNCH

EDIT PROGRAM AGE TABLE

FORMAT M4

CARD CODE

* PUNCH

CLIN: PROGRAM SUMMARY RECORDS

AIRCRAFT — FORMAT R1

SQUADRON or TYPE	CARD CODE	TAIL NUMBER	SORTIE TOUCHDOWN TIME					SHIFT	LOAD CONFIGURATION	H or P	S/F/L	NORS/G CODE		LAG		DELAY		FIX		RECOVERY		NORS		NORM		UNITS	MANHOURS		FLY TIME		RUN IDENTIFICATION
			YEAR	MO.	DAY	HR.	MIN.							HOURS	TENTHS	HOURS	TENTHS	HOURS	TENTHS	HOURS	TENTHS	HOURS	TENTHS	HOURS	TENTHS		HOURS	TENTHS	HRS.	TENTHS	
	7																														

2-DIGIT SYSTEM — FORMAT R2

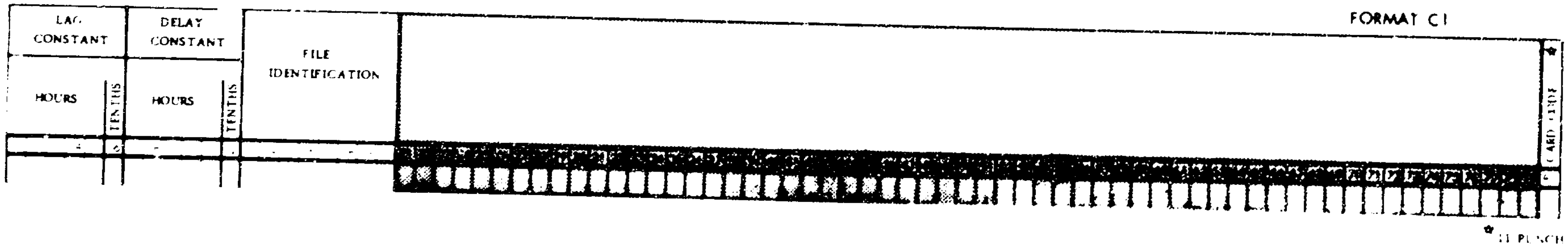
SQUADRON or TYPE	CARD CODE	TAIL NUMBER	SORTIE TOUCHDOWN TIME					SHIFT	LOAD CONFIGURATION	H or P	S/F/L	NORS/G CODE	2-DIGIT SYSTEM		LAG		DELAY		FIX		RECOVERY			UNITS	MANHOURS		FLY TIME		RUN IDENTIFICATION
			YEAR	MO.	DAY	HR.	MIN.								HOURS	TENTHS	HOURS	TENTHS	HOURS	TENTHS	HOURS	TENTHS			HOURS	TENTHS	HRS.	TENTHS	
	8																												

WORK CENTER — FORMAT R3

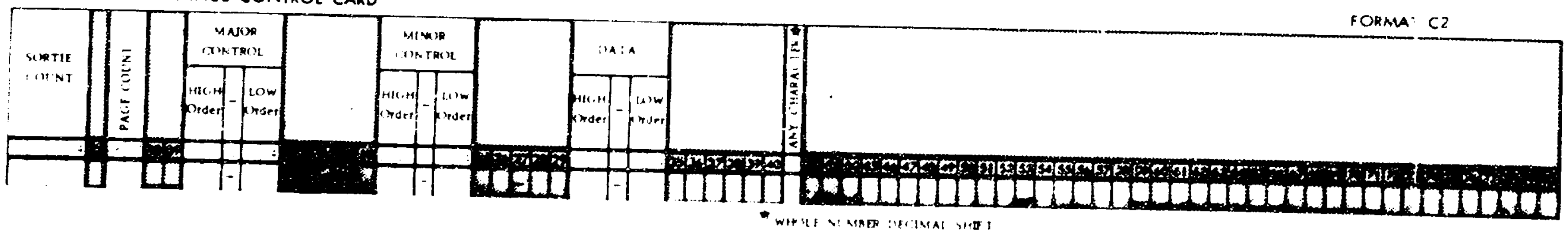
SQUADRON or TYPE	CARD CODE	TAIL NUMBER	SORTIE TOUCHDOWN TIME					SHIFT	LOAD CONFIGURATION	H or P	S/F/L	NORS/G CODE	WORK CENTER	LAG		DELAY		FIX		RECOVERY			UNITS	MANHOURS		FLY TIME		RUN IDENTIFICATION
			YEAR	MO.	DAY	HR	MIN.							HOURS	TENTHS	HOURS	TENTHS	HOURS	TENTHS	HOURS	TENTHS			HOURS	TENTHS	HRS.	TENTHS	
	9																											

PROGRAM CONTROL CARDS

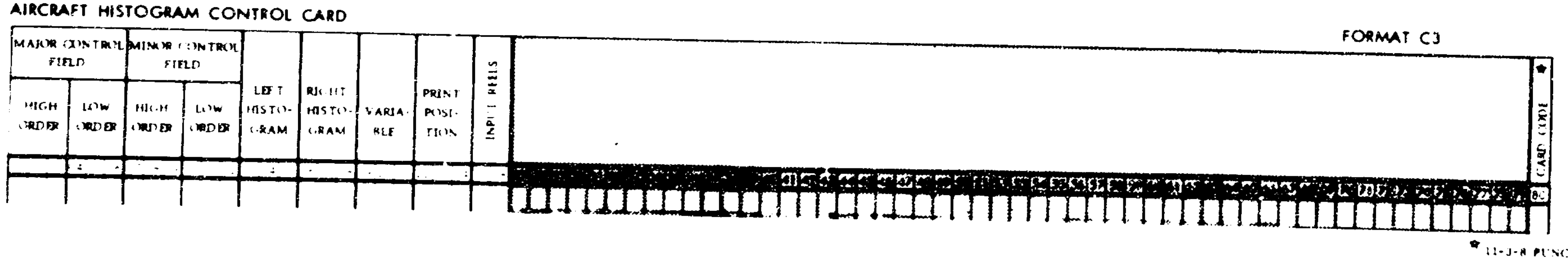
LAG/DELAY CONTROL CARD



ANALYSIS OF VARIANCE CONTROL CARD



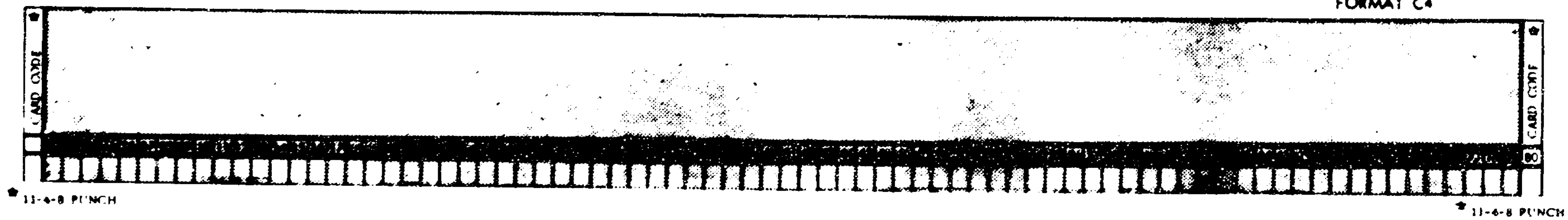
AIRCRAFT HISTOGRAM CONTROL CARD



PROGRAM CONTROL CARDS

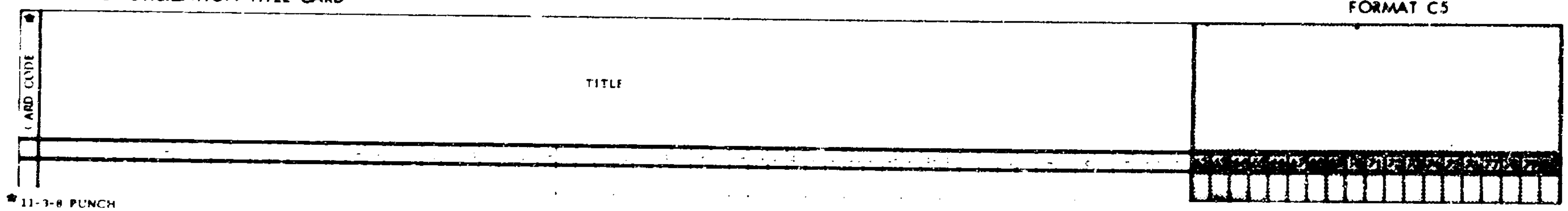
TABLE LOADING STOPPER

FORMAT C4



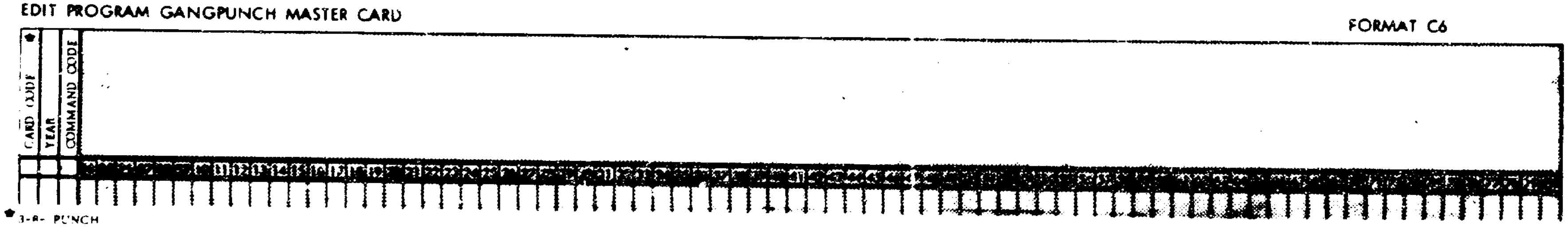
MANPOWER UTILIZATION TITLE CARD

FORMAT C5



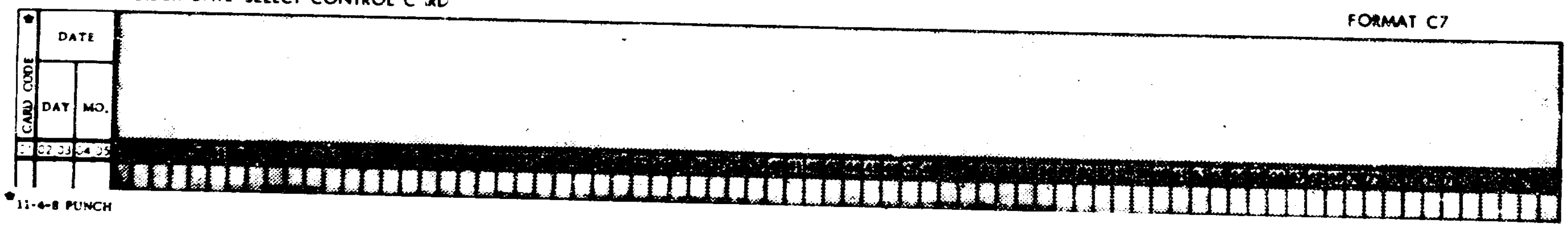
EDIT PROGRAM GANGPUNCH MASTER CARD

FORMAT C6

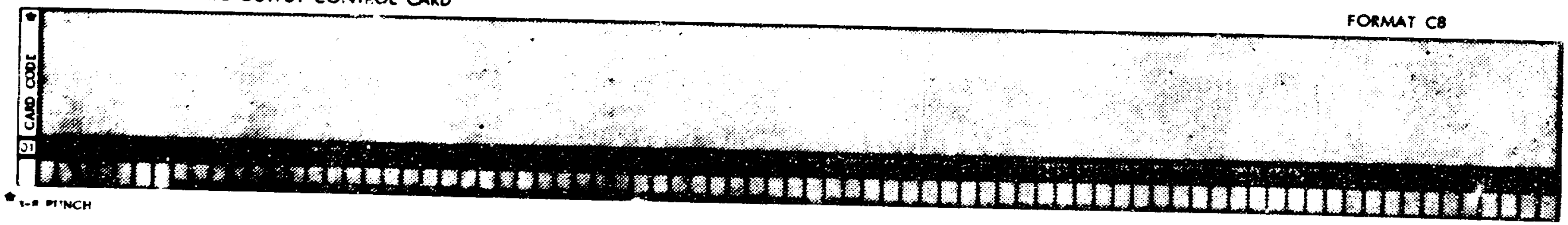


PROGRAM CONTROL CARDS

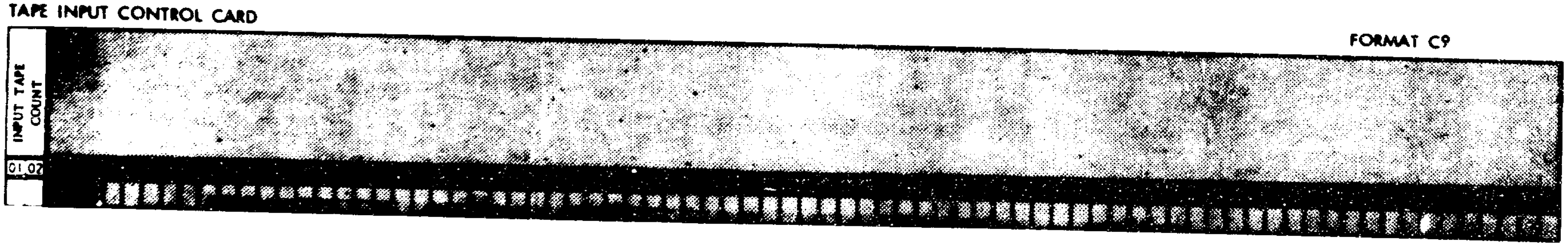
DISPLAY PROGRAM DATE SELECT CONTROL C RD



DISPLAY PROGRAM TAPE OUTPUT CONTROL CARD

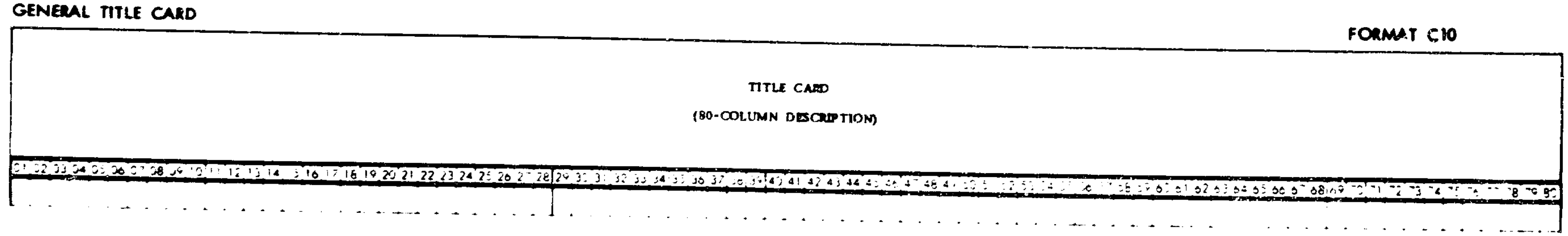


TAPE INPUT CONTROL CARD

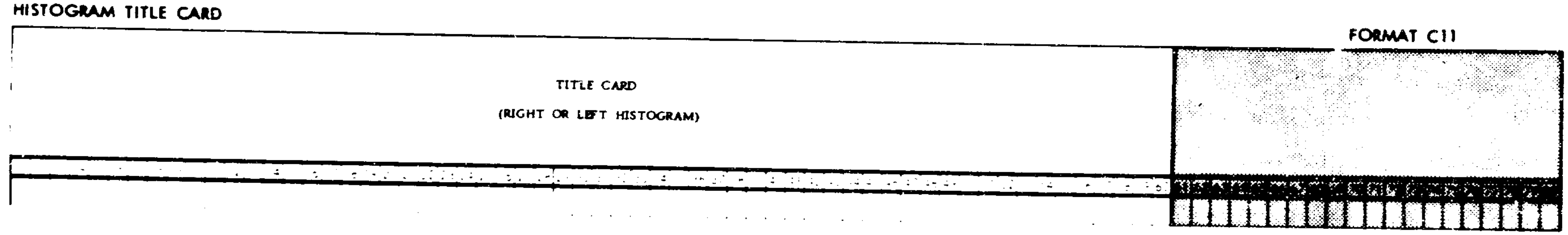


PROGRAM CONTROL CARDS

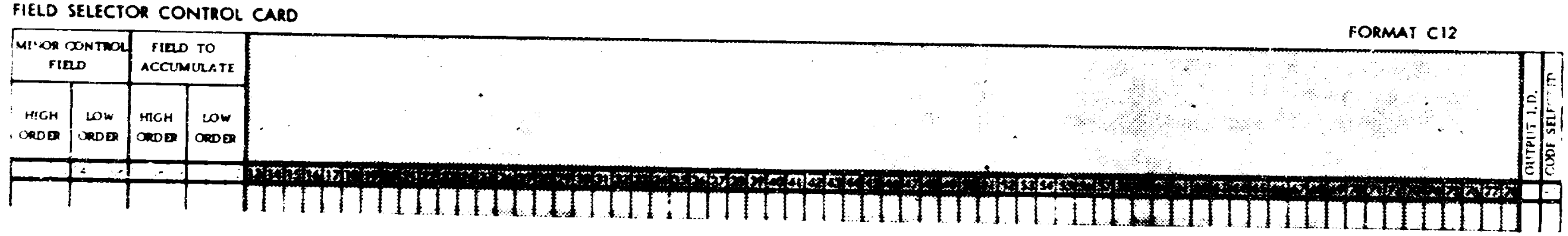
GENERAL TITLE CARD



HISTOGRAM TITLE CARD



FIELD SELECTOR CONTROL CARD



PROGRAM CONTROL CARDS

COMPUTE ELAPSED TIME PROGRAM – CODE SELECTOR

FORMAT C13

INPUT TAPE COUNT	CODE TO SELECT
01 02	03

FREQUENCY COUNT (FREQ) FIELD LOCATOR CARD

FORMAT C14

LOCATION FIELD 1		LOCATION FIELD 2		LOCATION FIELD 3		TITLE	CODE IDENT
HIGH ORDER	LOW ORDER	HIGH ORDER	LOW ORDER	HIGH ORDER	LOW ORDER		
01 02 03	04 05 06	07 08 09	10 11 12	13 14 15	16 17 18	19–79	80

CHI-SQUARE TITLE CARD

FORMAT C15

TITLE (1-79)	CARD CODE *
01–79	80

*12 PUNCH

PROGRAM CONTROL CARDS

CHI-SQUARE FIELD CONTROL CARD

FORMAT C16

LOCATION OF BASE-LINE COUNT		LOCATION OF OBSERVED FRE-QUENCY COUNT		LOCATION OF CATEGORY IDENTIFICATION		LOCATION OF MAJOR CONTROL		INPUT TAPE COUNT		CARD CODE *
HIGH ORDER	LOW ORDER	HIGH ORDER	LOW ORDER	HIGH ORDER	LOW ORDER	HIGH ORDER	LOW ORDER			80

* 11 PUNCH

CORRELATION FIELD DESIGNATION CONTROL CARD

FORMAT C17

VARIABLE NUMBER		MATRIX COLUMN HEADINGS		FIELD POSITION			ANY CHARACTER *	
				HIGH ORDER	LOW ORDER			19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 …

* WHOLE NUMBER DECIMAL SHIFT

CORRELATION GENERAL TITLE CARD

FORMAT C18

CARD CODE *	TITLE

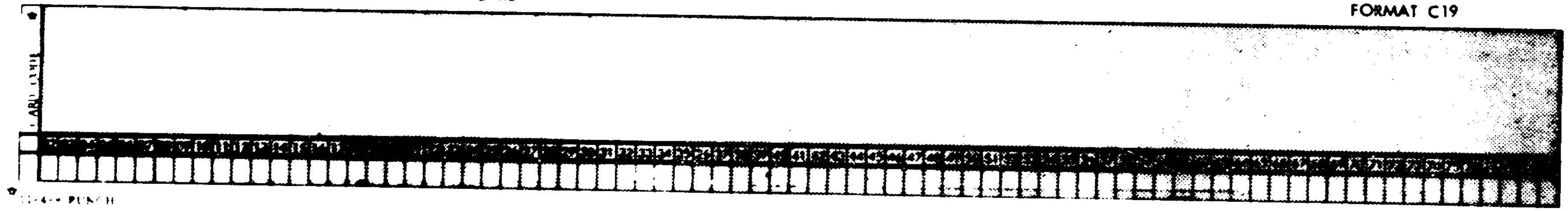
* 12-3-8 PUNCH

-97-

PROGRAM CONTROL CARDS

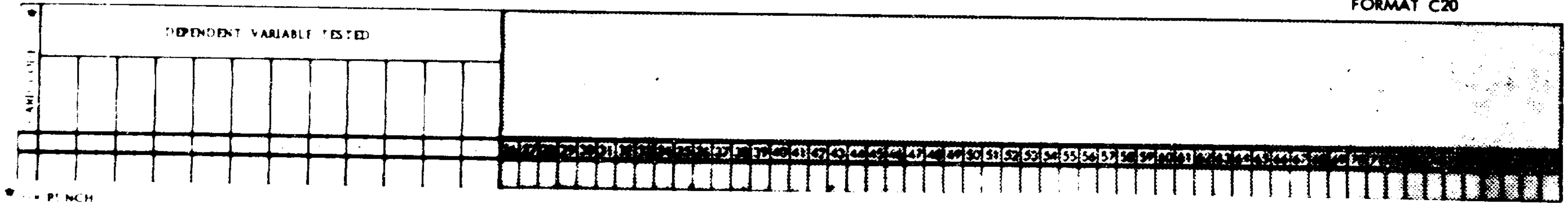
CORRELATION FIELD DESIGNATION TABLE STOPPER CARD

FORMAT C19



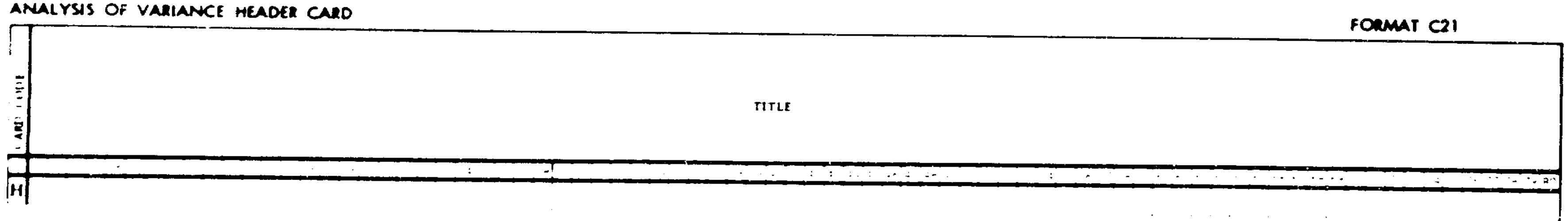
CORRELATION INDEPENDENT VARIABLE TEST CONTROL CARD

FORMAT C20



ANALYSIS OF VARIANCE HEADER CARD

FORMAT C21



COMBAT DRAGON CARD FORM 101 OPERATIONS CARDS

SORTIE DEBRIEFING

FORMAT CD1

CDM	TAIL NUMBER	DATE		FRAC NUMBER	CALL SIGN	PILOT	ABORT TYPE	ABORT REASON	TIME OF ABORT		RECOVERY DIVERSION	TIME OF DIVERSION		DIVERTED LOCATION	NAV TO TARGET	NAV RETURN	COMM TO TARGET	COMM RETURN	COMM ON TARGET	OPERATION SUPPORTED	GUN CAMERA	STRIKE CAMERA	ORDNANCE JETTISONED																CARD CODES	
		DAY	MO.						HR.	MIN.		HR.	MIN.										N	T	S/A	N	T	S/A	N	T	S/A	N	T	S/A	N	T	S/A	N	Z

DEBRIEFING OF COMBAT

FORMAT CD2

CDM	TAIL NUMBER	DATE		FRAC NUMBER	CALL SIGN	PILOT	FIRST TARGET	SECOND TARGET	THIRD TARGET	UTM COORDINATES			RENDEZVOUS WITH FAC	COMMUNICATION WITH FAC	FAC CONTROL	TARGET ACQUISITION	TARGET RETENTION	TACTICS USED	ORDNANCE ADEQUACY	COMMUNICATIONS	AIRCRAFT PERFORMANCE	TACTIC TARGET 1	TACTIC TARGET 2	TACTIC TARGET 3	CARD CODES	
		DAY	MO.							FIRST TARGET	SECOND TARGET	THIRD TARGET													P	Z

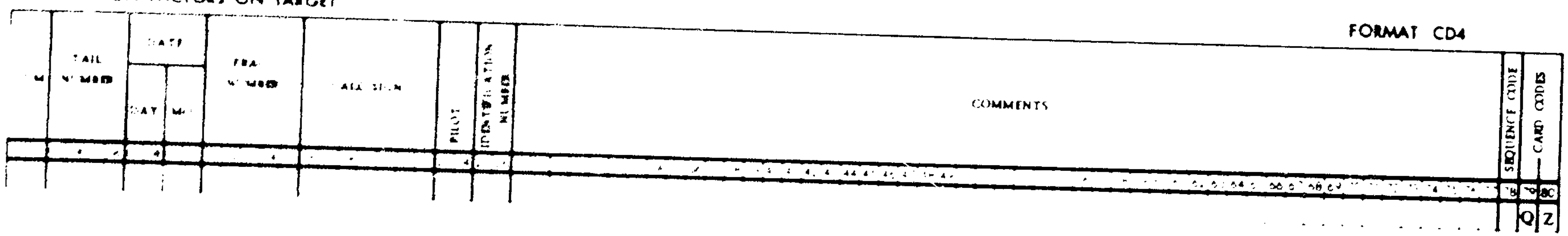
EN ROUTE DEGRADATION FACTORS

FORMAT CD3

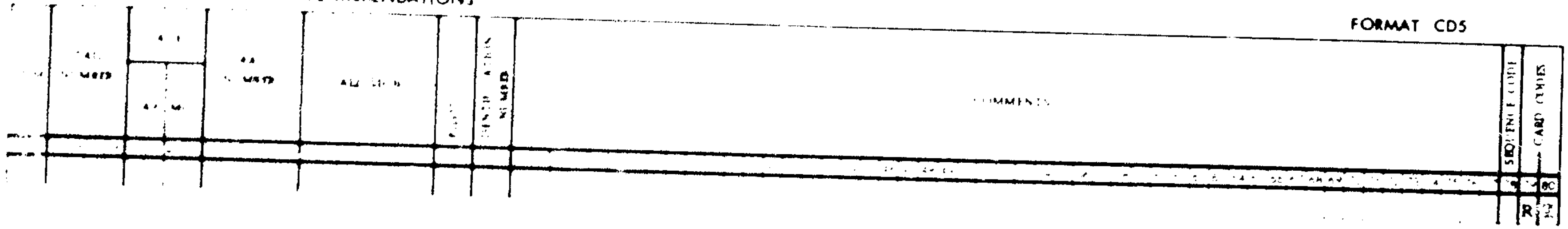
CDM	TAIL NUMBER	DATE		FRAC NUMBER	CALL SIGN	PILOT	IDENTIFICATION NUMBER	COMMENTS	SEQUENCE CODE	CARD CODES	
		DAY	MO.							O	Z

COMBAT DRAGON CARD FORM 101 OPERATIONS CARDS

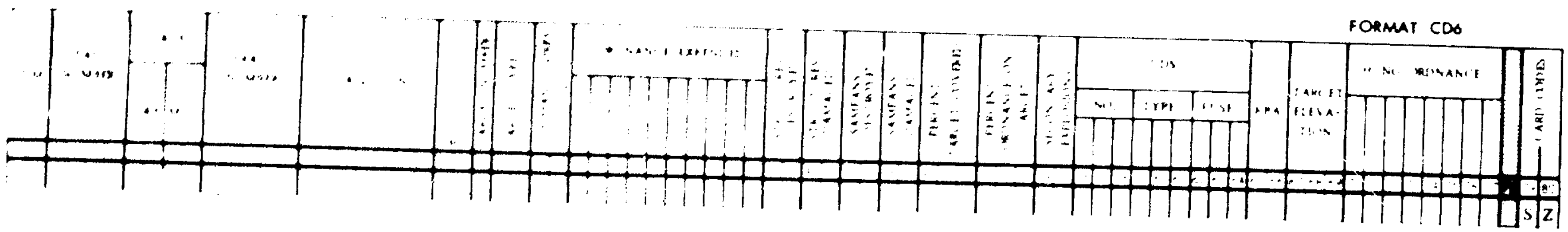
DEGRADATION FACTORS ON TARGET



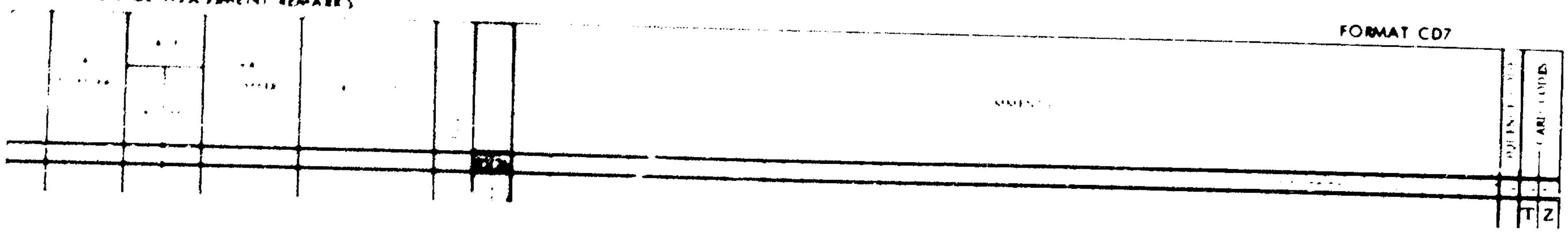
FLIGHT CREW COMMENTS AND RECOMMENDATIONS



BDA



BATTLE DAMAGE ASSESSMENT REMARKS



COMBAT DRAGON SUPPLY EDIT OUTPUT CARDS

DEMANDS, RECEIPTS, AND CANCELLATIONS CD Form 401, 402, June 1967 — FORMAT CD8

Stock Number	FSC	1–4
	Prefix	5–6
	FIIN	7–13
	Additional	14–17
Quantity		18–20
Unit of Issue		21–22
Supply Document Number	Service	23
	Account	24–26
	Shop	27–28
	Julian Date	29–32
	Serial Number	33–36
Delivery Priority		37–38
Tail Number		39–42
Equipment Type		43–47
Maintenance Document Number		48–53
Work Unit Code		54–58
Mission Number	Day	59–60
	Mo	61–62
	CDM	63–64
Fill or Kill		65
Time of Demand		66–69
Availability		70
Receipt or Cancel	Julian Date	71–74
	Clock Time	75–78
RKO		79
U		80

CANNIBALIZATION TAPE FORMAT — FORMAT CD9

Stock Number	FSC	1–4
	Prefix	5–6
	FIIN	7–13
	Additional	14–17
Quantity		18–19
Cannibalization Serial Number		20–22
Supply Document Number	Service	23
	Account	24–26
	Shop	27–28
	Julian Date	29–32
	Serial Number	33–36
Tail Number Part For		37–42
Equipment Type		43–47
Tail Number Part From		48–53
Work Unit Code		54–58
Maintenance Report Number for To Aircraft		59–64
Maintenance Report Number for From Aircraft		65–70
Time of Maintenance Control Action	Julian Date	71–74
	Clock Time	75–78
W		80

NORS: CD Form 403, June 1967 — FORMAT CD10

Stock Number	FSC	1–4
	Prefix	5–6
	FIIN	7–13
	Additional	14–17
Quantity		18–20
Supply Document Number	Service	23
	Account	24–26
	Shop	27–28
	Julian Date	29–32
	Serial Number	33–36
Tail Number		39–42
Equipment Type		43–47
Work Unit Code		54–58
In NORS	Julian Date	62–65
	Clock Time	66–69
Out NORS	Julian Date	71–74
	Clock Time	75–78
G N E A M X		79
X		80

COMBAT DRAGON SUPPLY EDIT INPUT CARDS

DEMANDS, RECEIPTS, AND CANCELLATIONS CD Form 401, 402, June 1967

FORMAT CD11

Stock Number	FSC	1–4
	Prefix	5–6
	FIIN	7–13
	Additional	14–17
Quantity		18–20
[illegible]		21–22
Supply Document Number	Service	23
	Account	24–26
	Shop	27–28
	Julian Date	29–32
	Serial Number	33–36
Delivery Priority		37–38
Tail Number		39–42
Equipment Type		43–47
Maintenance Document Number		48–53
Work Unit Code		54–58
Mission Number	Day	59–60
	Mo	61–62
	CDM	63–64
Fill or Kill		65
Time of Demand		66–69
Availability		70
Receipt or Cancel	Julian Date	71–74
	Clock Time	75–78
	Code	79
U		80

CANNIBALIZATION CARD FORMAT

FORMAT CD12

Stock Number	FSC	1–4
	Prefix	5–6
	FIIN	7–13
	Additional	14–17
Quantity		18–19
Work Unit Code		20–24
Serial Number Part For		25–30
Supply Document Number	Service	31
	Account	32–34
	Shop	35–36
	Julian Date	37–40
	Serial Number	41–44
Serial Number Part From		45–50
Time of Maintenance Control Notification	Julian Date	51–54
	Clock Time	55–58
Maintenance Report Number for To Aircraft		59–64
Maintenance Report Number for From Aircraft		65–70
Cannibalization Serial Number		71–73
X		74
Equipment Type		75–79
W		80

NORS: CD Form 403, June 1967

FORMAT CD13

Stock Number	FSC	1–4
	Prefix	5–6
	FIIN	7–13
	Additional	14–17
Quantity		18–20
X		21–22
Supply Document Number	Service	23
	Account	24–26
	Shop	27–28
	Julian Date	29–32
	Serial Number	33–36
X		37–38
Tail Number		39–42
Equipment Type		43–47
X		48–53
Work Unit Code		54–58
X		59–61
On NORS	Julian Date	62–65
	Clock Time	66–69
X		70
Off NORS	Julian Date	71–74
	Clock Time	75–78
[illegible]		79
X		80

DOCUMENT CONTROL DATA

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10. ABSTRACT

A description of the Rand/Tactical Air Command system for the collection, processing, and analysis of data, as implemented on an IBM 1401 computer, in the management and evaluation of aircraft operations and support at base level. The second volume in the series documenting the system presents the analysis package: the recovery sequence that summarizes the operations, maintenance, and supply data by sortie and the analysis programs that process the data from the recovery sequence and the editing sequence. The discussion is directed to maintenance analysts, to familiarize them with the available programs and analysis products. Companion volumes in the series are Vol. I: Data Collecting and Editing (RM-5666-PR); Vol. III: The Analysis Design and Methods (RM-5668-PR); and Vol. IV: The System Software (RM-5669-PR).

11. KEY WORDS

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